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Evaluation of Pipeline Reclamation Practices on Agricultural Lands in Alberta

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EVALUATION OF PIPELINE RECLAMATION PRACTICES ON AGRICULTURAL LANDS IN ALBERTA

Prepared for:

Reclamation Research Technical Advisory Committee

ALBERTA ENERGY AND NATURAL RESOURCES

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TABLE OF CONTENTS

		Page
1.0	EXECUTIVE SUMMARY	1
2.0	INTRODUCTION	6
2.1	Background	6
2.2	Purpose of the Study	6
2.3	Scope of the Study	7
2.4	Report Organization	9
2.5	Acknowledgements	9
3.0	METHODS	11
3.1	Approach	11
3.2	Methods	13
3.2.1	Task 1 - Review of Pipeline Construction and Reclamation Practices	13
3.2.2	Task 2 - Review of Available Literature on the Effects of Pipeline Construction and Reclamation on Agricultural Land	14
3.2.3	Task 3 - Site Selection and Field Examination of Existing Pipelines	14
3.2.4	Task 4 - Evaluation of Reclamation	18
4.0	RESULTS	19
4.1	Review of Available Information	19
4.1.1	Pipeline Construction and Reclamation Practices	19
4.1.1.1	Introduction	19
4.1.1.2	Right-of-way Width Requirements	20
4.1.1.3	Topsoil Stripping	21
4.1.1.4	Trenching	24
4.1.1.5	Stringing	25
4.1.1.6	Bending, Welding, Laying In and Testing of Pipe	26
4.1.1.7	Backfilling	27

	Page
4.1.1.8 Reclamation	27
4.1.1.9 Small Diameter (50 mm) Pipelines	30
4.1.2 Effects of Pipeline Trenching	30
4.1.2.1 Introduction	30
4.1.2.2 Soils	31
4.1.2.3 Vegetation	39
4.1.2.4 Conclusions	45
4.1.3 Reclamation Materials and Methods	46
4.1.3.1 Introduction	46
4.1.3.2 Topsoil Storage and Replacement	46
4.1.3.3 Wind Eroded Soils	56
4.1.3.4 Saline Soils	57
4.1.3.5 Sodic Soils	58
4.1.3.6 Water Eroded Soils	61
4.2 Summary of Field Data	63
4.2.1 Gray Luvisolic Soil Zone/ Peace River District	63
4.2.1.1 Gray Luvisolic Soils	68
4.2.1.2 Gray Solonetzic Soils	75
4.2.2 Black Soil Zone	77
4.2.2.1 Black Chernozemic Soils	78
4.2.2.2 Black Solonetzic Soils	89
4.2.3 Dark Brown Soil Zone	93
4.2.3.1 Dark Brown Chernozemic Soils	93
4.2.3.2 Dark Brown Solonetzic Soils	102
4.2.4 Brown Soil Zone	103
4.2.4.1 Brown Chernozemic Soils	112
4.2.4.2 Brown Solonetzic Soils	116

Page

5.0 DISCUSSION AND CONCLUSIONS 119

5.1 Topsoil/Subsoil Salvage and Replacement 119
5.1.1 Topsoil Salvage 119
5.1.2 Topsoil Replacement 119

5.2 Vegetation Responses 125

5.2.1 Annual Crop Response to Soil Salvage and Replacement Trends 125
5.2.2 Improved Forage Crop Response to Soil Salvage and Replacement 131
5.2.3 Native Pasture Response to Soil Salvage and Replacement 132

5.3 Effects of Age of Pipeline and Season of Construction 133
5.4 Topsoil Mixing and Crop Response 133
5.5 Effects on Irrigation Practices 134

6.0 RECOMMENDATIONS 136

6.1 Recommendations for Preconstruction Planning 136
6.2 Recommendations for Pipeline Construction 139
6.3 Recommendations for Post Construction Reclamation 140
6.4 Other General Recommendations 142
6.5 Recommendations for Additional Study 143

LITERATURE CITED 145

APPENDIX A. Characteristics of Sites With Decreased Vegetation - Gray Soil Zone 151

APPENDIX B. Characteristics of Sites With Vegetation Changes - Black Soil Zone 156

APPENDIX C. Characteristics of Sites With Decreased Vegetation - Dark Brown Soil Zone 166

APPENDIX D. Characteristics of Sites With Vegetation Changes - Brown Soil Zone 171

		Page
APPENDIX E.	Landowner/Farmer Questionnaire	176
APPENDIX F.	Site Legal Locations	180
APPENDIX G.	Analysis of Topsoil Samples at Selected Sites	184

LIST OF TABLES

		Page
Table 4.1	Soils studied by Toogood (1974).	32
Table 4.2	Soils studied by Button (1971) and DeJong and Button (1973).	33
Table 4.3	General seed mix specifications, suitable for mesic to xeric areas.	55
Table 4.4	Tolerance of crops for salts from the seedling stage onward (Sommerfeldt and Rapp 1977).	59
Table 4.5	Summary of sites evaluated.	65
Table 4.6	Summary of results showing changes in soil and vegetation on pipeline rights-of-way in the Gray Soil Zone/Peace River Region.	69
Table 4.7	Summary of results showing changes in soil and vegetation on pipeline rights-of-way in the Black Soil Zone: annually cropped land.	79
Table 4.8	Summary of results of differences in soil and vegetation on pipeline rights-of-way in the Black Soil Zone: forage cropland.	83
Table 4.9	Summary of results of differences in soil and vegetation on pipeline rights-of-way in the Dark Brown Soil Zone.	94
Table 4.10	Summary of results of differences in soils and vegetation on pipeline rights-of-way in the Brown Soil Zone.	104
Table 5.1	Frequency (number of sites) of soil salvage and mixing on sites with Chernozemic and Solonetzic soils in Alberta.	121
Table 6.1	Recommendation numbers (see text) for soil zone and farm practice.	137

LIST OF FIGURES

		Page
Figure 3.1	Schematic diagram of typical site location and sampling points.	16
Figure 4.1	Typical permanent right-of-way dimensions.	22
Figure 4.2	"Mormon Board" used for backfilling trench.	28
Figure 4.3	Conceptual diagram showing the trench area stripped with blade. Topsoil and subsoil piles windrowed on same side of trench.	47
Figure 4.4	Conceptual diagram showing the trench and subsoil pile areas stripped with blade. Topsoil and subsoil piles windrowed on same side of trench.	49
Figure 4.5	Conceptual diagram showing the topsoil stripped with blade. Topsoil and subsoil piles windrowed on opposite sides of trench.	50
Figure 4.6	Conceptual diagram showing the trench area stripped with ditcher. Topsoil and subsoil piles windrowed on same side of trench.	51
Figure 4.7	Conceptual diagram showing the topsoil stripped with ditcher. Topsoil and subsoil piles windrowed on opposite sides of trench.	52
Figure 4.8	Conceptual diagram showing the method used for construction of a particular water pipeline. Topsoil and subsoil stripped with scraper and used immediately for backfilling or placed in small piles on spoil side of trench.	53
Figure 4.9	Typical herringbone erosion control terracing of slopes.	62

		Page
Figure 4.10	Soil zones of Alberta.	64
Figure 5.1	Frequency of topsoil salvage on pipeline right-of-way sites investigated in Alberta.	120
Figure 5.2	Vegetation changes on right-of-way sites investigated in Alberta.	126
Figure 5.3	Vegetation changes on pipeline right-of-way sites investigated on Solonetzic soils in Alberta.	127
Figure 5.4	Vegetation changes on pipeline right-of-way sites investigated on non-Solonetzic soils in Alberta.	128
Figure 5.5	Relative frequency of poorer annual crops, tame pasture and native pasture on pipeline right-of-way sites investigated in the Black and Gray Soil Zones in Alberta.	129
Figure 5.6	Relative frequency of poorer annual crops, tame pasture and native pasture on pipeline right-of-way sites investigated in the Brown and Dark Brown Soils in Alberta.	130

1.0 EXECUTIVE SUMMARY

The purpose of the study was to review available information on pipeline reclamation practices on agricultural land in Alberta, define the effects of pipeline construction and reclamation on the land, and recommend optimal reclamation techniques which will minimize the adverse effects.

Information from the literature and unpublished industry sources was reviewed to determine the pipeline construction and reclamation practices used in Alberta, and outline the effects on soil capability and farm practices. Following the review, a field survey of 154 sites on existing pipeline rights-of-way through annually cropped, irrigated, and improved forage and native pasture lands in each of the major soil zones in Alberta, was conducted.

At each site, soil profile characteristics, vegetation cover and height, were noted on the trench, working and stockpile areas, as well as on an adjacent location in the same soil type which was undisturbed by pipeline construction. Crop head length and weedy species type and abundance were also noted at many sites. Questionnaires were circulated to the landowners of each site to gather information on reclamation from their point of view.

The results of the field survey were processed and presented as differences or changes over the trench, working and stockpile areas relative to the adjacent undisturbed areas (controls).

Topsoil was salvaged at approximately half of all the sites examined, predominantly over the trench areas only. Salvage was most common in the Black and Gray soil zones and on annually cropped and

irrigated land. Depth of salvage varied from 10 to 45 cm. Unmixed topsoil was replaced over the trench at 20 of the 154 sites and was found in a similar proportion over the stockpile areas. About half of the working areas had unmixed topsoil at the surface. The remainder of the sites had varying degrees of mixed topsoil, subsoil (B horizon) and parent material (C horizon) or no topsoil on the surface. The high frequency of mixing or burial of topsoil is potentially the result of a combination of factors including:

- the common method of stockpiling topsoil adjacent to and often abutting the spoil pile;
- the commonly used "Mormon Board" and/or bulldozer for backfilling;
- the presence and disposal by levelling over the right-of-way of excess spoil as a result of bulking or displacement by the larger pipes;
- topsoil salvage deeper than the depth of topsoil present; and
- additional traffic and introduction of additional soil material when rebackfilling and levelling is needed after trench settlement, particularly on irrigated land.

Poorer crops were found at 44 percent of the annually cropped sites. These crops were thinner, shorter and/or weedier than adjacent control areas. Poorer crops were least common at sites in the Black Soil Zone and on Solonetzic soils in the Brown Soil Zone. Canola appears to be less sensitive to the right-of-way disturbances than wheat, oats, barley and fall rye. All four irrigated annually cropped sites had poorer growth over the right-of-way, corresponding to the mixed topsoil and compacted subsoil over the right-of-way.

Fifty-four percent of the improved forage sites and 81 percent of the native pasture sites had poorer growth characteristics, as indicated by reduced vegetation cover and height and/or increased weediness on the rights-of-way. Weediness on the right-of-way was a recurring trend at many sites, while landowners encountered management difficulties at a few sites resulting from different seeded grass species on the right-of-way, compared to the adjacent areas.

Poorer annual crop growth on the rights-of-way was most common on sites of 3 years or less in age in the Black and Gray soil zones. In the drier Brown and Dark Brown soil zones, poorer annual crop growth was found on sites up to 23 years old.

Poorer improved and native forage crops and weedier conditions were found on rights-of-way of all ages in all soil zones. Weeds were most noticeable in the Brown Soil Zone and in other zones where Canada thistle was dominant.

Even though topsoil was mixed with subsoil and parent material at many sites, this did not always result in poorer crops. This was particularly evident on annually cropped sites in the Black Soil Zone. Soil settlement over the trench and subsoil compaction were most evident at irrigated sites. Additional backfilling and levelling was needed to allow the continuation of irrigation practices.

Recommendations

The recommendations resulting from this study include support for preconstruction reclamation plans based on topsoil surveys which document topsoil characteristics, location, and characteristics of

Solonetzic topsoil and subsoil (parent material), poorly drained areas and high erosion risk soils. It is also recommended that, where possible, affected landowners be included in the reclamation planning process, particularly where the land is under irrigation or managed pasture.

Recommendations for the construction phase focus on improved accuracy in topsoil handling and spoil disposal to minimize topsoil-subsoil mixing, particularly in the drier Brown and Dark Brown soil zones and on all Solonetzic soils. These recommendations include:

- separate stockpiles for topsoil and spoil;
- topsoil salvage on stockpile areas as well as on the trench;
- disposal of excess spoil offsite or by levelling on the right-of-way before replacing topsoil;
- restricting or curtailing vehicle and machinery traffic on the right-of-way during wet weather; and
- maintenance of supervision to ensure contractor compliance with reclamation specifications.

Recommendations for post construction reclamation focus on weed control which was a recurring problem on tame and native pasture sites in all soil zones. Cultivation of topsoil and subsoil is recommended to loosen compacted areas and where trench settlement has occurred, it is recommended that the trench be rebackfilled with soil of similar quality to that in the surrounding field. In forage land and native pasture, species should be selected for revegetating the right-of-way which are compatible with the surrounding vegetation and with the pasture management objective. The use of starter fertilizer and restriction of grazing in the first growing season will also improve the

success of grass/legume establishment and reduce the chance of excessive weed establishment.

Additional studies are recommended to define:

- critical limits of salinity and sodicity in spoil below the replaced topsoil;
- tolerance limits of annually cultivated land through mixing of topsoil and subsoil;
- to verify impacts found on irrigated crop and forage land, and research reclamation methods which will minimize physical disturbance of irrigated soils; and
- optimal methods and limits of soil handling under winter conditions.

The current industry efforts to develop improved soil salvage and replacement equipment and to test equipment designed to improve seedbed conditions in sandy wind erodible soils should be encouraged and supported.

2.0 INTRODUCTION

2.1 Background

Underground pipeline construction has resulted in varying degrees of surface disturbance throughout Alberta. The degree of surface disturbance will vary with the size of pipe installed (commonly from 150 mm to 1420 mm diameter), construction methods, timing and reclamation procedures. Landscape features such as topography, soil type and drainage will also affect the nature and degree of disturbance.

There is concern that the potential productivity or land capability to produce annual crops, forage and native pasture on agricultural land in Alberta may be significantly reduced with some types of pipeline construction. Furthermore, pipeline construction activities may disrupt farm management techniques temporarily or in the long term.

To minimize such disturbances, the Reclamation Research Technical Advisory Committee has requested that Hardy Associates conduct a study to evaluate pipeline reclamation practices on agricultural land in Alberta.

2.2 Purpose of the Study

The purpose of the study is three-fold:

1) to gather and review pertinent information on past and present pipeline reclamation practices on cultivated fields, tame pasture and native pasture lands in Alberta;

2) to define the effects of pipeline reclamation practices in terms of types and magnitudes on the range of agricultural lands in Alberta; and

3) to recommend optimal pipeline reclamation techniques on agricultural land in Alberta that will minimize adverse effects on these lands.

2.3 Scope of the Study

The study addresses the effects of construction and reclamation of a range of pipeline sizes from 76.2 mm to 1219 mm in diameter. A description of the major types of pipeline construction and reclamation techniques associated with varying pipe size or purpose has been prepared and their differences relative to surface disturbance noted.

The following terms are used in this review to describe conditions peculiar to pipeline installations. The ditch in which the pipe is buried and the surface area on which soil was stored during pipeline installation are referred to as the trench and the stockpile area respectively.

The conditions under which various pipeline construction and reclamation techniques have been examined include:

- major soil zones/regions including the Gray Luvisolic, Black, Dark Brown and Brown soil zones;
- soil types within each zone/region that may present special

problems and require different reclamation treatment from other soils, including Solonetzic soils, sandy soils and poorly drained soils; and

- cultivated fields (irrigated and non-irrigated), native pasture and tame pasture (irrigated and non-irrigated).

The specific reclamation treatments examined include:

- topsoil[1] salvage (no salvage, salvage over trench, salvage over stockpile and/or working areas);
- topsoil replacement (unmixed, mixed with parent material, mixed with B horizon only, buried with spoil);
- location of topsoil stockpiles (adjacent to (abutting) subsoil pile, same side of trench or opposite side of trench from subsoil pile);
- seedbed preparation (none, cultivation, ripping compacted surface);
- erosion control methods, including contouring, diversion ditches or dykes, mulching and use of special vegetation;
- revegetation, fertilization and soil amendments, including type of seed mixes, fertilizer additions, liming and mulching;
- timing of construction and reclamation (winter/summer); and
- treatments used on double trenched right-of-way, including reclamation over new trench, reclamation over both trenches and reclamation of the whole right-of-way.

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1 For the purposes of this study, topsoil is defined generally as the depth of the soil A horizon in undisturbed profiles or the depth of the plow layer (Ap) in cultivated soils.

The effects of the reclamation treatments on the various soil conditions listed above have been assessed in terms of differences in soil capability between disturbed areas and adjacent undisturbed areas, and short and long term disruption of farm management practices.

The effects of pipeline reclamation on soil capability and farm management practices were related to elapsed time since pipeline construction and reclamation.

2.4 Report Organization

The methods used for the review of available information, site selection, and examination and evaluation of the data are presented in Section 3.0. The results of the review and summary of field results are presented in Section 4.0. Discussion of the trends shown in soil productivity, surface configuration and farm management under various soil and farm conditions in response to topsoil handling, revegetation and time is presented along with conclusions in Section 5.0. Recommendations regarding optimum reclamation practices are presented in Section 6.0.

2.5 Acknowledgements

This project was made possible by support from that portion of the Alberta Heritage Trust Fund administered by the Alberta Land Conservation and Reclamation Council. The assistance of Dr. P.F. Ziemkiewicz, Chairman, Reclamation Research Technical Advisory Committee is gratefully acknowledged.

The guidance and assistance of the Pipeline Reclamation Steering Committee (Mr. John C. Hermans, Soils Branch Alberta Agriculture, Chairman) was most appreciated.

The authors wish to acknowledge all of the cooperating companies who provided information on pipeline construction, reclamation methods, and route alignment and location data. These companies include Nova, An Alberta Corporation, Shell Canada Resources Ltd., TransAlta Utilities Ltd., Gulf Canada Resources Inc., Canadian Western Natural Gas Company Limited, Northwestern Utilities Ltd., Foothills Pipe Lines (Yukon) Ltd., Peace Pipe Line Ltd., Banister Pipelines and Henuset Bros. Ltd. The cooperation of the Department of Agriculture (District Agriculturists) and landowners is also gratefully acknowledged.

3.0 METHODS

3.1 Approach

As outlined in the scope of the project, the relative success of the variety of pipeline reclamation practices depends on a large number of construction and environmental variables.

An evaluation of these variables supported by data on differences in crop yield, soil nutrients and soil physical properties would require the following general approach:

1) review of pipeline construction and reclamation practices used in Alberta;

2) review of available literature (published and industry reports) on the effects of pipeline construction and reclamation on soil capability and farm practices;

3) field survey of existing pipeline routes to document general success or failure of pipeline reclamation for the variety of field conditions and provide an indication of causes of success or failure;

4) group the pipeline reclamation practices according to general success or failure, and under what field conditions;

5) make general recommendations based on the reclamation treatments that are successful for each field condition;

6) isolate key pipeline construction and reclamation techniques, soil zones, soil type and field conditions (cultivated, tame or native pasture) which have the greatest effect on soil capability and farm management, and for which additional information is required on successful reclamation;

7) design and conduct a quantitative evaluation of the effects of the key variables isolated in 6) on crop yield, variety of crops that can be grown, soil fertility and soil physical properties such as moisture holding capacity, erodibility and compaction; and

8) recommend the optimum reclamation practices which minimize the adverse effects of pipeline construction on soil capability and farm management, based on quantitative evaluation.

The focus of this study is on the first six items in order to evaluate and document the variety of pipeline construction and reclamation methods over the range of soil and farm conditions. The results of this study include:

- recommendations as to which pipeline reclamation techniques tend to be successful and under what soil conditions and farm management types; and
- recommendations for further study as to which pipeline construction and reclamation practices and which soil conditions may require quantitative evaluation to provide sound guidelines for successful reclamation.

3.2 Methods

The following tasks were conducted to complete the study as outlined above.

Task 1 - Review of pipeline construction and reclamation practices.

Task 2 - Review of available literature on the effects of pipeline construction and reclamation on agricultural land.

Task 3 - Site selection and field examination of existing pipelines.

Task 4 - Evaluation of reclamation practices and report preparation.

3.2.1 Task 1 - Review of Pipeline Construction and Reclamation Practices

This task involved a review of the range of methods and sequences of pipeline construction and reclamation used in Alberta. Differences in methodology due to size and purpose of the pipeline and the preferred method (based on engineering and economic constraints) for different field conditions were noted.

This task included consultation with major pipeline engineering and construction companies. The most common methods of construction and reclamation were identified together with variations resulting from the type of equipment, size of pipeline, soil conditions or landowner requests.

3.2.2 Task 2 - Review of Available Literature on the Effects of Pipeline Construction and Reclamation on Agricultural Land

This task involved gathering and summarizing available published and industry reports describing the effects or relative success of pipeline reclamation in Alberta or other similar areas. Published information is limited but included work in Alberta and Saskatchewan conducted by universities and industry. Information on reclamation of other industrial projects was reviewed and summarized during Task 2 for later use in evaluating pipeline reclamation and recommending optimum treatments.

3.2.3 Task 3 - Site Selection and Field Examination of Existing Pipelines

Based on the reviews conducted in Tasks 1 and 2, sites in each soil zone were selected for field examination under a variety of soil conditions and types of farm operation.

The following process was involved in selecting field sites:

- obtain pipeline system maps from cooperating companies with information on size and age of lines;
- select pipelines of varying size and age in each soil zone and in Chernozemic and Solonetzic soil areas of each zone;
- obtain alignment sheet segments for pipelines selected together with any available construction details;
- review from available soil survey reports, the types of soils expected along each alignment sheet segment. Where photomosaic

alignment sheet bases were available, farm type could also be determined;

- list potential sites by soil zone, type of farm, pipeline size, age, construction season and legal location;
- obtain permission from landowners to evaluate sites;
- final site selection was based on field confirmation of soil condition and farm type. To expedite field examination, as many sites as possible were selected close together within a particular soil zone/region and easily measured data which reflect differences in soil capability were gathered. Field evaluation was conducted primarily in July and August 1981 when crops and forage were sufficiently mature to evaluate; and
- the right-of-way cross section at each selected site was placed according to the location of the desired soil type and crop within the farm property, where soil conditions could be expected to be uniform prior to installation of the pipeline. In addition, the cross section was located within each field, a sufficient distance from roads, fencelines, hedgerows and other features so that any soil disturbances from activities near these features were eliminated from the study. The cross sections were finally placed randomly on the right-of-way with regard to crop or soil condition on the right-of-way. Variations in these conditions along the right-of-way were included by taking data on the cross section and at four other points along the right-of-way (trench, stockpile, work area) and control at 5 m intervals away from the selected cross section as indicated in Figure 3.1.

At each site the following specific data were gathered from over the trench, stockpile and working areas, and over an undisturbed (by pipeline construction) adjacent area:

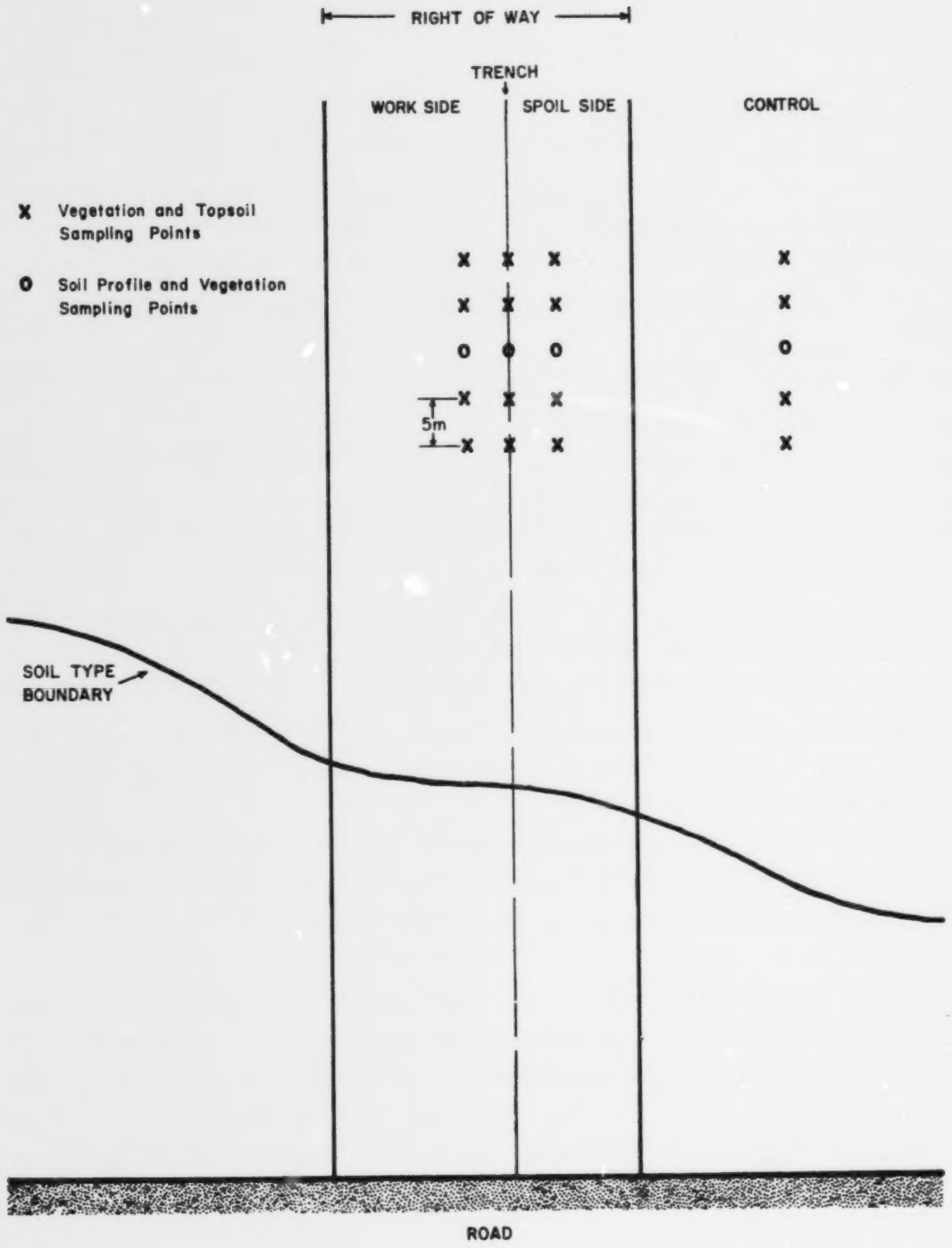


Figure 3.1
SCHEMATIC DIAGRAM OF TYPICAL SITE LOCATION AND SAMPLING POINTS

- type of farm operation;
- crop height;
- crop cover and composition (dominant and significant species including invading weeds);
- soil type;
- topsoil and subsoil depth, texture (hand), consistence and stoniness;
- evidence of mixing of topsoil and subsoil;
- evidence of erosion;
- evidence of compaction in topsoil and subsoil using a standard pocket penetrometer;
- presence of salts, stones or other conditions that may affect soil capability; and
- where an obvious difference in crop height and/or cover and composition was evident and the cause not clear, representative soil samples were gathered for analysis to determine possible causes for the difference. Analysis included macronutrients, pH, conductivity, soluble salts and organic matter content.

Each site was also documented with pipeline construction and reclamation information as available and included pipeline diameter, age, construction season and method of soil salvage.

Where possible, the documentation also included the observations of the landowners/farmers at each site. A questionnaire was circulated to landowners/farmers to record their observations (Appendix E). Approximately 10 percent of the questionnaires were returned completed or partially completed. A photographic record of vegetation conditions at each site is available on file.

3.2.4 Task 4 - Evaluation of Reclamation

Site records (field data and documentation) were categorized on the basis of obvious differences in crop growth between affected and unaffected areas. The following general categories were used:

- crop height and cover obviously greater on trench, stockpile and/or working area than adjacent unaffected area;
- crop height and cover not different from adjacent unaffected area; and
- crop height and cover obviously lower on trench, stockpile and/or working area than adjacent unaffected area.

Where differences occur the potential pipeline-related causes were noted based on the data collected, soil analyses and professional observations in the field.

From this assessment, the optimum pipeline reclamation methods and materials were recommended. Where cause of differences were not obvious or information on successful topsoil salvage and reclamation was deficient, recommendations were made as to the direction and type of research that may be needed before optimum reclamation practices can be recommended.

The report includes text, summary tables, figures and diagrams in 8.5 x 11 format. Site data including the photographic record has been compiled in an organized manner and kept on file.

4.0 RESULTS

4.1 Review of Available Information

4.1.1 Pipeline Construction and Reclamation Practices

4.1.1.1 Introduction

Most of the pipelines installed to date throughout Alberta are high pressure gas pipelines ranging from 150 mm to 1017 mm in diameter. Construction has almost always taken place during the summer or fall in agricultural areas although less frequently, construction has occurred during winter when the ground was frozen. With the exception of some smaller diameter lines (50 mm), equipment and procedures used for gas and oil pipeline construction are similar. However, construction of large diameter water pipelines may involve some methods and equipment not used for gas and oil pipeline construction, although the general sequence of construction is similar.

In this section, the range of methods and equipment used during the various stages of pipeline construction are presented. Included is a discussion of the conventional sequence and methodology of right-of-way width requirements, trenching, pipe preparation and placement (stringing, bending, welding, sagging and testing), backfilling, and reclamation. A review of recent technology regarding the placement of small diameter pipelines concludes this section.

The information presented herein has been obtained through communications with a number of pipeline contractors, engineers and reclamation specialists employed by the following companies: Banister

Pipelines, Canadian Western Natural Gas Company Limited, Foothills Pipe Lines (Yukon) Ltd., Gulf Canada Resources Inc., Hardy Associates (1978) Ltd., Henuset Bros. Ltd., Northwestern Utilities Ltd., Nova, An Alberta Corporation, Peace Pipe Line Ltd., Shell Canada Resources Ltd. and TransAlta Utilities Ltd.

4.1.1.2 Right-of-way Width Requirements

A minimum permanent right-of-way width of 15 m is generally required for construction across agricultural lands. A number of pipelines have been constructed within a right-of-way width of 10 m, however, construction efficiency is often severely limited under such confined conditions.

Permanent right-of-way width requirements are dependent on pipe diameter and/or on the number of lines being placed. These requirements are directly related to trench size and subsequent topsoil and subsoil storage area requirements. Right-of-way widths of 15 m to 20 m are often associated with pipe diameters ranging from 100 mm to 200 mm whereas a right-of-way width of 22 m to 27 m is common where pipe sizes range from 200 mm to 900 mm. Where two pipelines have been placed in a common ditch, a right-of-way width of 30 m or more may be required to accommodate a wider trench, greater soil storage area and both pipelines on the surface prior to placement in the trench.

The right-of-way width used for pipeline construction becomes the "Permanent Right-of-way" for the life of the pipeline. However, specific construction procedures such as road bores and pipe welding at stream crossings may require a wider working surface to accommodate more machinery and the larger volumes of soil stripped and excavated. In

these areas "Temporary Work Space" is obtained for the duration of construction. At road crossings, an additional 5 to 10 m may be required, whereas extra space needs at river crossings may vary from an extra 10 m, to two or three times the permanent right-of-way width, depending on the complexity of the crossing.

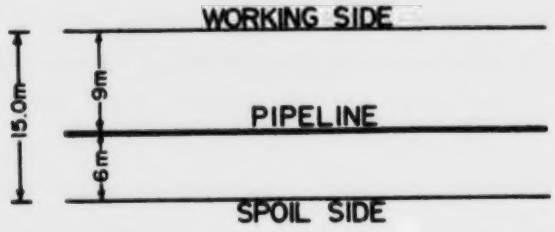
Within the permanent right-of-way, the ditchline centre is generally 1/3 of the way from one side and 2/3 from the other (Figure 4.1). Equipment movement and operations are carried out on the wider zone (working side), whereas the narrower zone (spoil side) is used for temporary storage of excavated material.

The right-of-way is usually marked with small flagged stakes. In some instances, temporary fences are constructed, but this is usually done only at the request of the landowner. Fences usually consist of four strands of barbed-wire with treated posts.

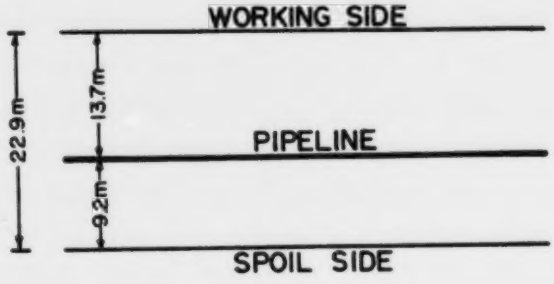
4.1.1.3 Topsoil Stripping

A survey of pipeline companies indicates that virtually all pipeline construction during the past 10 to 15 years has included plans for topsoil stripping in agricultural areas. In some cases, these plans have been limited to locations where landowners have requested topsoil salvage. In most cases, only the trench area is stripped, although, on cultivated areas in particular, topsoil has also been stripped from the area used to store the subsoil excavated from the trench. Infrequently, and only at the request of the landowner, the entire right-of-way will be stripped. The actual width of the area stripped of topsoil depends

A Single 203 mm Pipeline



B Single 609 mm Pipeline



C 863.3 mm Mainline and 863.3 mm Loop

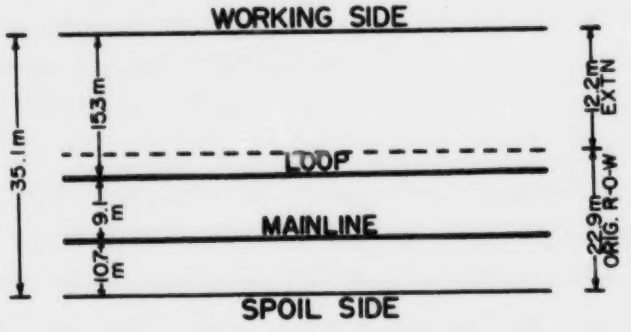


Figure 4.1
TYPICAL PERMANENT RIGHT-OF-WAY DIMENSIONS

mostly on the equipment used for the stripping operation. The width of stripping will be a multiple of bulldozer blade width and number of passes made.

In a few cases in Alberta, and more often in Ontario and Quebec, landowners have requested that no topsoil be stripped. The reasons for this are unclear although the land in question in the eastern provinces has heavy textured soil located in areas of relatively high precipiation. Consequently, the adverse physical effects of handling wet clayey topsoil may offset any benefits of salvage and replacement.

Since 1980, topsoil surveys have been conducted in Alberta along a number of pipeline routes to estimate the depth and type of soil encountered. In addition, these surveys usually evaluate erodibility, salinity, sodicity and other factors which may influence the salvage and reclamation procedures.

Maximum and minimum salvage depth limits are usually established prior to salvage operations. Salvage depths seldom exceed 30 cm, even though the A horizon may extend beyond this depth. Conversely, it is considered that salvage of topsoil shallower than 10 cm becomes impractical, because of the limits of equipment and difficulty in replacing a uniform, thin layer of topsoil.

Several methods of topsoil salvage are available to the operator, usually depending on the equipment available. All methods require equipment which can remove the designated soil from the trench and move it to the appropriate storage area. The most commonly used equipment is the bulldozer or rubber tired grader, both of which push

the soil material on to the storage area. Other types of equipment in use include the ditcher-conveyor, scraper, backhoe and most recently, a power dozer. The power dozer is a conventional bulldozer with a hydraulically driven track attachment above the cutting blade. The blade scrapes the soil in front of the dozer so the track can move the soil laterally to either side. Replacement can be done in a similar manner.

For the construction of a particular water pipeline, a scraper was used in the topsoil stripping operation. In this instance, the topsoil was either dumped in piles along the spoil side of the right-of-way or immediately transported and spread over the backfilled portion of the line. Backhoes are often used to strip topsoil in wet areas. In at least one instance, however, backhoes were used for topsoil stripping along the entire length of the line.

If construction has occurred during winter months on frozen ground, the topsoil, where salvaged, has been ripped by a bulldozer prior to stripping.

4.1.1.4 Trenching

The depth of the trench usually ranges from 1 m to 1.5 m for oil and gas pipelines. The trench depth for water pipelines is generally dependent on the anticipated maximum depth of seasonal frost penetration. The width of the trench is dependent mostly on the size of the pipe, but it is also related to pipe flexibility and equipment availability. In general, the trench is 30 cm to 60 cm wider than the width of the pipe.

In almost all cases, trenching is done by a ditcher and the spoil material is conveyed to the area adjacent to the trench on the spoil side of the right-of-way. Backhoes may be used to excavate the trench in wet areas but they are seldom used to trench the entire line. For the construction of water pipelines, scrapers have been used to excavate the spoil material to a depth level with the top of the pipe and the remainder is excavated by a backhoe.

In some situations, such as when the pipeline crosses irrigation canals or treed section boundaries, the pipe may be placed through a bored hole rather than in a trench.

4.1.1.5 Stringing

Pipe is brought to the construction site on flatbed tractor-trailers. Each truck carries its maximum load irrespective of pipe size. Therefore, in general, more trucks pass over a particular portion of the pipeline route when large diameter pipe is installed as opposed to smaller pipes. However, the number of trips down the right-of-way by stringing trucks is dependent on access as well as pipe size. Where possible, loaded stringing trucks should drive directly over the planned ditch line.

Pipe off-loading is generally done using side boom dozers ranging in size from D6 to D9 depending on the size of the pipe. Truck-mounted cranes have been used to off-load concrete pipe used for water pipelines.

The pipe is usually placed end to end along the route although breaks may be left in the line when crossing native pastureland or to allow passage of wildlife and/or livestock at the landowner's request.

Stringing usually precedes trenching at a distance of 1 to 5 km. In rare instances, such as in the construction of concrete pipelines, the pipe may be off-loaded and placed immediately in the trench.

4.1.1.6 Bending, Welding, Laying In and Testing of Pipe

Pipe bending is usually done in the field by a bending machine that varies in size according to the size of the pipe. On some large diameter pipelines (greater than 500 mm), bending is usually done during the manufacturing process.

Welding equipment is mounted on trucks with a capacity of 1 ton or more. The number of welding trucks at a particular construction site is variable. One to six welding trucks may be used on a small diameter (150 mm) pipeline whereas as many as fifty might be used for the construction of a large diameter (900 mm) pipeline.

Bulldozer sidebooms are generally used to lower the sections of the pipe into the trench. These range in size (e.g., D7 to D9) depending on the size of the pipe. The number of sidebooms at a particular pipeline construction site varies from 3 to 25 or more.

Hydrostatic pressure testing of oil and gas pipeline is usually undertaken after backfilling.

Water required for hydrostatic testing is usually obtained from a nearby stream and returned to this stream after use. After testing, methanol is used to dry the pipe. The methanol is recovered and retained until it can be disposed of at an industrial waste facility. The lengths of pipe tested at any particular time varies from several hundred metres to several kilometres, depending on location and/or changes in construction method. Shorter test sections are often located at road crossings or locations with pipeline sag bends.

4.1.1.7 Backfilling

Backfilling is usually done with a bulldozer and blade or with a "Mormon Board" attached to a sideboom or crane (Figure 4.2). In most cases the spoil material is backfilled and tamped with a bulldozer or rubber-tired vehicle and then the topsoil is spread over the area that had previously been stripped. In some areas, however, where separate topsoil replacement has not been specified, both the topsoil and subsoil piles are backfilled simultaneously.

Any excess subsoil, as a result of the installation of large diameter pipe, is usually levelled over the right-of-way, and is consequently not readily observed. In some cases, particularly in pastureland, excess spoil is spread over the trenched area to a height of as much as 0.5 m above the original ground level to allow for subsidence.

4.1.1.8 Reclamation

Reclamation along the route is usually done immediately

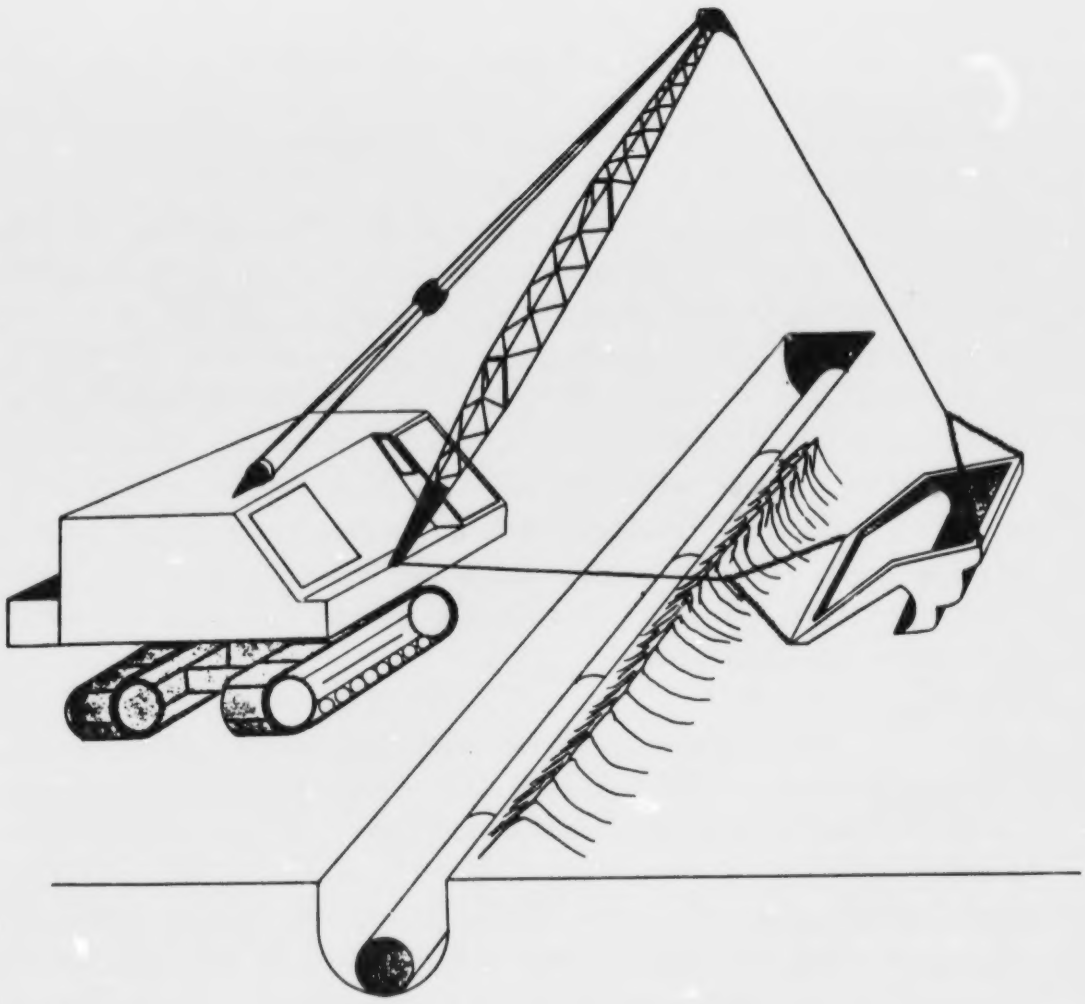


Figure 4.2
'MORMON BOARD' USED FOR BACKFILLING TRENCH

following construction. Stones are picked to a level acceptable to the landowner and the excavated area is recontoured and disced or harrowed.

In cultivated land, further reclamation work is usually done by the landowner or subcontracted to a local farmer. This work includes cultivating compacted soil, fertilizing and reseeding.

In recent years, most reclamation in pasture land has been done by the pipeline company. Reclamation in these areas is usually confined to the trenched portion of the right-of-way and takes place immediately following construction. When construction takes place during late fall or winter, reclamation is done the following spring. Reseeding of pasture land is done using either a standard seed mix or a mix based on specific site conditions. However, the landower is always given the opportunity to request that a particular seed mix be applied. Most reseeding is done either by ground broadcasting from cyclone seeders, drilling, or using brillion-type seeders. At least one company hydroseeds all pasture land.

A number of additional reclamation activities may be required at specific sites. Temporary fences are removed although in some cases, these have been left at the landowner's request. On steep slopes, cross ditches have been constructed across the right-of-way to reduce erosion. Where construction has taken place during the summer, areas of subsidence along the route are usually infrequent and localized. Winter construction, however, often results in extensive subsidence along the trenched portion of the right-of-way. Subsidence, in the form of piping, may also occur where runoff or irrigation water concentrates on the backfilled trench area. Where subsidence has occurred, topsoil is hauled to the site and spread to the original contours at the site.

Along one pipeline, topsoil was hauled in and placed along portions of the route where severe mixing of the topsoil and subsoil had occurred.

4.1.1.9 Small Diameter (50 mm) Pipelines

In recent years, for the installation of most 50 mm pipelines, the conventional method of pipeline construction has been replaced by a procedure commonly referred to as "plowing in".

The basic operating equipment consists of a wide-framed four-wheeled carrier, that contains a spool of pipe pulled by a dozer with a plow attached to the rear. During operations, pipe is continually fed from the spool into a plowed ditch. The spool contains 1067 m of steel or aluminum pipe which limits the amount of welding of pipe joints. After installation of the pipe, the plow-line is compacted.

4.1.2 Effects of Pipeline Trenching

4.1.2.1 Introduction

This review deals with the available information describing the effects or relative success of pipeline reclamation in Alberta and similar areas. Effects of pipeline installation on soils precedes a discussion of the effects on vegetation. Specific topics such as irrigation and soil types are dealt with in each section.

Following the discussion of the effects of pipeline installation on vegetation, reclamation methods and materials are described. Topsoil salvage and replacement, species suitability and revegetation techniques are included.

In cases where information directly concerning pipeline reclamation is not available, general reclamation or soils literature is used as a source. Mining reclamation studies from the Northern United States, Saskatchewan and Alberta are the most common sources of such information.

Trench width and depth varies with pipeline size and/or soil type. The pipeline trenches studied by Button (1971) and DeJong and Button (1973) were generally 45 cm wide and 90 cm deep though some were 60 cm wide and 120 cm deep. Pipeline trench dimensions, on sites studied by Toogood (1974) ranged from 50.8 cm wide by 101.6 cm deep for a 168 mm pipe diameter to 101.6 cm wide by 188 cm deep for a 864 mm pipe diameter (Table 4.1).

4.1.2.2 Soils

Button (1971) and DeJong and Button (1973) reported the effects of pipeline trenching on Chernozemic and Solonetzic soils (Table 4.2) in the Black and Dark Brown soil zones. Effects on both chemical and physical properties of soils were reported.

In general, changes in chemical properties due to trenching depend on initial mixing, subsequent tillage and changes in physical properties of the soil. The fertility of the top 15 cm of the reclaimed trench was not significantly lower than that of the undisturbed soil (DeJong and Button 1973).

Table 4.1. Soils studied by Toogood (1974).

Soils	Pipe Diameter-Type (mm)	Trench Dimensions (cm)
Orthic Dark Gray	168 - gas	50.8 x 101.6
Eluviated Black and Orthic Dark Gray	610 - oil	76.2 x 162.6
Black Solodized Solonetz and Eluviated Black	864 - oil	101.6 x 188.0
Eluviated Black	406 - oil	61.0 x 121.9
Black Solodized Solonetz and Eluviated Black	610 - oil	76.2 x 162.6
Eluviated Black and Dark Gray Wooded	610 - oil	76.2 x 162.6
Black Solodized Solonetz and Eluviated Black	610 - oil	101.6 x 188.0
Black Chernozemic Malmo silty clay	not available	61.0 x 121.9

Table 4.2. Soils studied by Button (1971) and DeJong and Button (1973).

Zone	Soil	Profile
Chernozemic Soils		
Dark Brown	Weyburn loam	Orthic and Solonetzic-like
Dark Brown	Weyburn loam	Orthic and Solonetzic-like
Dark Brown	Weyburn loam	Orthic and Solonetzic-like
Black	Oxbow loam	Rego calcareous
Black	Oxbow loam	Orthic
Black	Ryerson loam	Calcareous
Solonetzic Soils		
Dark Brown	Estevan loam	Solod
Dark Brown	Estevan loam	Solod
Dark Brown	Estevan loam	Solod
Dark Brown	Estevan loam	Solod
Dark Brown	Trossachs loam	Solodized-Solonetzic
Dark Brown	Trossachs loam	Solodized-Solonetzic

Chemical Properties

Mixing of the A, B and C horizons due to trenching did not change NO_3-N or P concentrations in the 0-15 cm layer, however, there were significant increases in Na, Ca and Mg levels and a significant decrease in K. At the 30-60 cm depth there was a significant increase in NO_3-N, P and K indicating that significant amounts of topsoil were incorporated during pipeline installation (DeJong and Button 1973).

A significant increase in P, Na, Ca and Mg on the stockpile area was probably due to considerable amounts of the Ap horizon left on the soil surface (DeJong and Button 1973, Button 1971). On Oxbow loams, considerable subsoil in the stockpile area was still visible after ten years. Significantly lower NO_3-N levels were found in stockpile areas originating from these soils.

Salt concentrations in the trench, determined by measuring electrical conductivity, increased in the upper 0-30 cm level while concentrations decreased in the 30-60 cm depth when compared to undisturbed sites. Conductivity levels, above 4 mmhos/cm, were found in disturbed Solonetzic soils. Stockpile area values for electrical conductivity were also significantly higher than undisturbed sites on Solonetzic and the Chernozemic Weyburn loam. On soils developed on nonsaline parent materials, conductivity in the surface horizons was not significantly increased by pipeline installation (Button 1971). Salt concentrations on stockpile areas of Solonetzic soils decreased with time (three years) though not below those values for adjacent undisturbed sites.

An increase in pH was observed in both Chernozemic and Solonetzic soils (DeJong and Button 1973) though the magnitude of the change varied with soil order. Changes in pH due to trenching in Chernozemic soils were less than 0.5 units with the exception of Weyburn soils in which changes of up to 1.0 units were observed. Trenches and stockpiles on Solonetzic soils were characterized by changes of up to 2.0 units. In general, changes in pH coincided with similar changes in electrical conductivity.

Limited research has shown that topsoil stockpiling has little effect on microbial biomass in the short-term. Stockpiling of Bow City topsoil had no significant effect on either respiration or microbial biomass over a period of four months (Parkinson et al. 1980). Whether soil microbe biomass and respiration will be affected by the replacement of stockpiled topsoil is not known. Miller and May (1978, as cited by Parkinson et al. 1980) observed that for changes in soil aggregation and organic nitrogen to occur, two years of topsoil storage were required before any detrimental effects could be measured.

No information is available with regard to the effects of pipeline trenching on soil chemistry in the Gray Soil Zone. Related information from mine reclamation work at Judy Creek (Hardy Associates 1981b) indicates that if topsoil is not replaced, pH is higher (7.4), organic matter levels are lower (1.4 percent) and K levels increase compared to topsoil. Addition of 30 or 70 cm of topsoil results in a moderately acidic pH (5.5-5.9) and organic matter levels of 2.0 to 2.5 percent. Nitrate nitrogen is low in both topsoil and subsoil although P and K are adequate for plant growth in both soils.

Physical Properties

DeJong and Button (1973) categorized changes in soil physical properties on the basis of soil order. Physical properties of Chernozemic soils were neither harmed nor improved by trenching (DeJong and Button 1973), while in Solonetzic or Solonetzic like soils, physical properties were improved.

Chernozemic Soils

Increased bulk densities in the trenches of some Chernozemic soils were attributed to compaction by heavy machinery. In an Oxbow Orthic loam, bulk density increased from 1.2 g/cm^3 in undisturbed soil to 1.4 g/cm^3 in the trench. Aeration of Chernozemic soils was not affected.

Halvorson et al. (1980) reported that compaction by machines, of trenches containing sandy loam soil, resulted in considerably higher bulk densities (1.57 g/cm^3) when compared to uncompacted trenches (1.24 g/cm^3). Finer textured clay loams and silty clay loams did not seem to change in bulk density under compaction. None of the soils in Halvorson's study were sodic in nature.

Moisture holding capacity, in the study by Halvorson et al. (1980), was not affected by compaction with the exception of sandy loam soils. The addition of topsoil to trenches containing sandy loams resulted in increased water contents in the top 120 cm. Water contents in clay loam or silty clay loam soils did not increase with the addition of topsoil.

In Chernozemic soils available water to a depth of 60.4 cm was equal to or greater than that in the undisturbed field (Button 1971). Generally the differences in potential available water in the trench and undisturbed field were small.

Sodium adsorption ratios (S.A.R.) in an Oxbow soil were increased in the top 30 cm of the trench and stockpile area. This increase reflected a decrease in soluble Ca concentration.

Solonetzic Soils

The physical properties of Solonetzic soils are improved by trenching operations. Pipeline installation breaks up the impermeable Bnt horizon and improves water permeability, air filled pore space and relative diffusivity (Button 1971). Sodium adsorption ratios (S.A.R.) were generally higher in the top 15 cm depth of the trench and stockpile area than on undisturbed sites. Two years after pipeline installation in a Solonetzic Estevan loam, S.A.R. values in the top 15 cm of the trench, stockpile area and undisturbed field were 4.9, 4.1 and 0.8 respectively. Significant increases in S.A.R. were recorded for the 0-15 cm depth of the trench and stockpile area of 2 to 3 year old pipelines in the Estevan loam and in the trench of the Weyburn loam. S.A.R. was also significantly increased in the trench at depths of 15-30 cm and 30-60 cm in Weyburn soils (Button 1971). These increases in S.A.R. were not expected to affect soil structure. In addition, S.A.R. values were less than those reported to be restrictive to crop growth (Krogman 1973, Canadian Department of Agriculture 1964). Significant differences in S.A.R. between disturbed soil, in the trench and stockpile area and undisturbed soil were not recorded for pipelines 4 years or older.

The air filled pore space of Solonetzic soils is normally barely adequate even though oxygen diffusion rates are satisfactory. Trenching improved both air filled pore space and oxygen diffusion rates of Solonetzic soils. Bulk density in the Bnt horizon of an Estevan loam decreased slightly from 1.55 to 1.4 g/cm^3.

Trends with regard to available water in Solonetzic soils were variable. One Solonetzic soil (Estevan loam) had higher available water in the trench than in the undisturbed field but the opposite occurred in another Solonetzic soil (Trossachs loam). Problems with determination of moisture content limited conclusions in the papers by Button (1971) and DeJong and Button (1973).

Since pipeline installation can involve trenching to a depth of 180 cm, it is very similar to deep plowing, which is a technique used to improve Solonetzic soils. Deep plowing of Solonetzic soils involves cultivation to a depth of 60-75 cm in order to break up the columnar Bnt horizon (Karkanis and Cairns 1980). Penetration to the lime salt layer is required in order to redistribute Ca and Mg from lower to upper soil depths (Krogman 1980). Ca and Mg displace Na from the soil exchange sites, resulting in the breakdown of columnar blocks in the Bnt horizon.

Karkanis and Cairns (1980) found that deep plowing of solonetzic soils under irrigation, especially when it was combined with fertilization, resulted in significant downward movement of soluble salts and leaching of P, N, K and particularly Ca.

Surface horizons of some Solonetzic soils may be very acid (Nyborg 1978). Hermans (1981) indicated that the increase in $CaCO_3$,

brought to the surface by deep plowing, increased soil pH and consequently improved the potential for crop production. Breakup of the Bnt layer and the resultant lower bulk density and increased moisture storing capability are all factors which contributed to improved root penetration and crop growth.

Kjearsgaard (1980) warns against deep plowing in areas of groundwater discharge or areas with shallow subsurface water tables. Upward movement of salts may occur in such situations (Karkanis and Cairns 1980) resulting in unfavorable soil physical properties with respect to plant growth.

Deep plowing studies have implications with regard to trenching. Physical properties such as bulk density, permeability and aeration will all improve with respect to plant productivity when trenching occurs in Solonetzic soils. Long-term improvements in plant productivity also depend on 1) whether fertilizer or soil amendments such as gypsum are used 2) if the lime salt layer is present and mixed with surface soil and 3) if the area is irrigated. If water discharge areas or areas with shallow subsurface water tables are present the longevity of changes in physical properties beneficial to crop production will be reduced. Finally, the mixing of highly sodic parent materials into the 0-60 cm layer may impede the amelioration of the Bnt horizon and reduce crop yields.

4.1.2.3 Vegetation

Button (1971), DeJong and Button (1973) and Toogood (1974) reported the effects of pipeline trenching on crop yield. Changes in

vegetation cover on trenched pipelines in pastures were documented by Reid (1977).

In general, there is an improvement in yield with time on Solonetzic soils while yields on Chernozemic soils are not affected or increased slightly. Compaction can affect yield on sandy soils. Revegetation on pasture land depends on soil type and species present on nearby undisturbed sites. Areas with sandy soils are very susceptible to wind erosion.

Crops

Toogood (1974) reported that for Black Chernozemic soils, there was a general improvement in yield on trenched areas. In four of the fields sampled, grain yield of oats and barley was significantly greater on the pipeline than on undisturbed fields. Five fields on Black Chernozemic Malmo silty clay soils showed no significant change in yield while one field decreased significantly in wheat yield. Wheat and barley yields on other soil types showed a uniform increase in grain yield, though straw yields were not significantly different. Grain was usually taller over the pipeline, however, there were fewer plants per unit area than in the undisturbed field.

DeJong and Button (1973) found no significant difference in wheat yields on disturbed and undisturbed Chernozemic soils in Saskatchewan except for a Ryerson loam where there was a significant increase in yields. This increase was thought to be due to an increase in NO_3-N in the trench. P increases in the trench were not expected to increase yield.

On Solonetzic soils, wheat yields on recent trenches did not exceed those on undisturbed fields. Significantly higher wheat yields were found on trenches 8 to 10 years of age and were attributed to a decrease in salt content with time and improved soil structure (DeJong and Button 1973).

Krogman and McKay (1980), in a laboratory study, found that horizon mixing in loam textured Solonetzic soils increased crop growth but not in similar textured Solodic or Chernozemic soils. The authors concluded that mixing of soil horizons may increase plant growth where soil moisture is severely restrictive by promoting more uniform rooting with depth.

Significant decreases in yield were reported on pipeline trenches and rights-of-way in Ontario. Production on the trench decreased to 55 percent (small grains or grain corn) of undisturbed areas on clay, 61 percent (silage corn) on loam and 84 percent (grain corn) on sand (Shields 1979). Decreases in production continued over a number of years. These decreases in yield were related to low total nitrogen in the surface soil, a 10 percent increase in bulk density and a 35 percent decrease in the capacity of the soil to transmit water. Mixing of topsoil with subsoil, soil compaction, and rutting were cited as causes of change in physical characteristics.

The apparent conflict in conclusions between these reports may be due to the nature of the areas studied. Many of the areas in Shields' study had tile drainage systems. The soils studied by Button (1971) were naturally well drained loamy soils. Climate, lack of drainage due to compaction, poor aeration, water logged soils and upward migration of salts may be responsible for the difference in yields

between this study (Shields 1979) and those of Toogood (1974) and DeJong and Button (1973).

Halvorson et al. (1978) found that compaction reduced wheat yield on sandy soils but not on clay loams or silty clay loams. The yield decreases resulting from compaction were not directly related to a decrease in moisture holding capacity since the total water content of compacted trenches was higher for only the clay loam materials. Significant increases in bulk density were found only in the sandy loam soil. No differences were found in the clay loam or silty clay loam. Therefore, differences in yields cannot be fully accounted for by bulk density differences.

Pasture Land

Pasture land is generally land which is unsuited for cultivation due to limitations imposed by unfavorable climate, topography and/or soil characteristics. Soil textures in pasture land vary from sandy loam to silty clay while physiography ranges from stabilized sand dunes to valley bottoms. Revegetation and erosion characteristics can be much different from cultivated land.

All of the information available with respect to the effects of pipeline installation on pasture land, deals with native grasslands. Reid (1977) studied the effects of pipeline installation (24.4 m right-of-way, pipe diameters from 762 mm to 1967 mm) on pasture land in the Eastern Alberta Plain, Saskatchewan River Lowland, Sand Hills Plain, Cypress Hills Upland, Wood Mountain Upland, Fort Vermilion and Peace River Lowlands, Porcupine Hills Upland, Foothills and aspen parkland in the Fort Vermillion and Peace River Lowlands. Hardy Associates (1979,

1980) monitored revegetation, in the Middle Sand Hills, of pipelines installed using the plowing technique (50-75 mm pipe) and conventional ditching (200 mm pipe). Differences in vegetative cover, between disturbed and undisturbed sites, were reported in this study.

Eastern Alberta Plain, Saskatchewan River Lowland, Sand Hills Plain, Cypress Hills Upland and Wood Mountain Upland

Reid (1977) reported that disturbance of pasture land: was minimal for well drained soils in the Eastern Alberta Plain, Saskatchewan River Lowland, Sand Hills Plain, Cypress Hills Upland and Wood Mountain Upland. The presence of a 15 year old pipeline right-of-way was barely noticeable on the rangeland of the Crawling Valley. Sparse revegetation and minor water erosion were found on some of the steeper valley banks. Natural revegetation resembled adjacent undisturbed sites and included species such as sagebrush (Artemisia cana), needle grass (Stipa comata) and pasture sagewort (Artemisia frigida).

More recent disturbances had a variable cover of crested wheatgrass (Agropyron cristatum), if seeded, or weedy species including foxtail barley (Hordeum jubatum), Russian thistle (Salsola kali), Canadian thistle (Cirsium arvense) and gumweed (Grindelia squarrosa).

Rapidly drained sandy soils in these areas are subject to wind erosion. Removal of plant cover results in the formation of blowouts or bare areas of shifting sand which are subsequently colonized by skeleton weed (Lygodesmia juncea), sunflower (Helianthus petiolaris), rice grass (Oryzopsis hymenoides) and Canada Wild Rye (Elymus canadensis). On a recently established pipeline right-of-way, a sparse cover of prairie

rose (Rosa arkansana), sunflower and pasture sagewort (Artemisia frigida) was present. Older disturbances and stabilized blowouts are colonized by buckbrush (Symphoricarpos occidentalis), prairie rose and wild licorice (Glycyrrhiza lepidota). These areas are extremely sensitive to any type of disturbance, such as pipeline installation, road construction and grazing, and must be carefully managed. Selective grazing on pipelines has been found to hinder revegetation in sandy soils (Hardy Associates 1980).

The plowing in technique, (Section 4.1.1.9) was used in the Middle Sand Hills to facilitate revegetation, minimize displacement of topsoil and reduce erosion due to wind. This technique involves laying pipe into a narrow preripped trench, up to 150 cm in depth. Soil disturbance is limited to the narrow zone above the pipeline and the topsoil remains fairly well in place. Total vegetation covers ranged from 35 to 80 percent over plowed in lines while trenched lines of similar age in the same area exhibited little growth and some localized erosion (Hardy Associates 1980).

Porcupine Hills Upland

In the Porcupine Hills Upland, pipeline installation has not resulted in significant erosion after 13 years. Natural revegetation has occurred over most of the right-of-way to the extent that the species composition and cover closely resemble adjacent overgrazed or disturbed grasslands (Reid 1977). The most common grass on the right-of-way is Timothy (Phleum pratense).

Foothills

Pipeline installation has resulted in minimal disturbance to the vegetation and soils of the Foothills after a period of approximately 13 years. Initially, there is little or no revegetation due to the large amount of exposed, coarse parent material. Soil erosion is restricted to local areas where spring runoff has caused some gullying; however, constructed waterways and coarse textured soils have prevented severe erosion. Natural revegetation by species such as Kentucky bluegrass (Poa pratensis), black medick (Medicago lupulina), common mullein (Verbascum thapsus), silverly cinquefoil (Potentilla argentea) and pussy toes (Antennaria nitida) covers about 88 percent of the ground, though there can be considerable variation.

Fort Vermillion and Peace River Lowlands

The aspen parkland in the Fort Vermillion and Peace River Lowlands consists of prairie patches and aspen bluffs with prairie occupying the drier sites. No information with regard to revegetation of grassland in these areas is available.

4.1.2.4 Conclusions

In summary, the major problem along pipeline rights-of-way in the grassland areas of Alberta is likely to be wind erosion, especially on sandy soils. A consequence of unchecked erosion is the destruction of useful pasture land both on the right-of-way and in adjacent lands. Erosion is aggravated by vehicular traffic and heavy grazing (Reid 1977).

Wind erosion of sandy soils in the Middle Sand Hills, was minimized through the use of the plowing technique of pipeline installation. Minimal disturbance of the topsoil and rapid re-establishment of native grasses and herbs limit the amount of wind erosion. For the same reasons, there is a low abundance of weedy species in these areas (Hardy Associates 1980).

Water erosion is of little consequence in most areas including river banks since revegetation of either natural or seeded species was adequate. Eroding areas seem to be repaired promptly by the pipeline companies, especially in cases of slopes where the integrity of the pipeline could be jeopardized (Reid 1977).

4.1.3 Reclamation Materials and Methods

4.1.3.1 Introduction

This section deals with reclamation of pipeline related disturbances in saline and/or sodic soils, soils subject to wind and water erosion, as well as topsoil management and replacement on pipeline trenches. Various methods used to deal with problems identified in the effects section are discussed.

4.1.3.2 Topsoil Storage and Replacement

Topsoil and subsoil can be removed and stored in a variety of configurations commonly including:

1. Topsoil from trench piled separately from subsoil on same side of trench (Figure 4.3) with blade equipment;

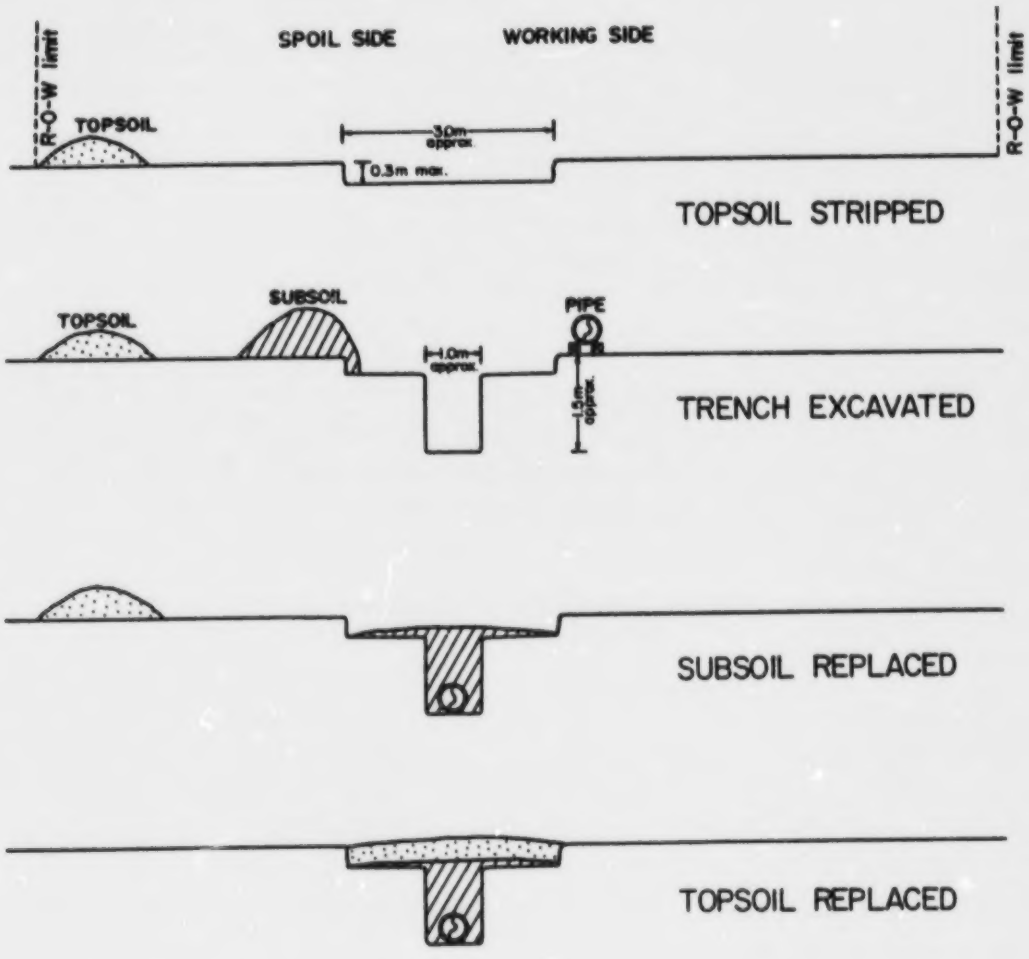


Figure 4.3
CONCEPTUAL DIAGRAM SHOWING THE TRENCH AREA STRIPPED WITH BLADE. TOPSOIL AND SUBSOIL PILES WINDROWED ON SAME SIDE OF TRENCH.

2. Topsoil from trench and subsoil storage areas piled separately from subsoil on same side of trench (Figure 4.4) with blade equipment;

3. Topsoil from trench piled separately from subsoil on opposite side of trench (Figure 4.5) with blade equipment;

4. Topsoil from trench piled adjacent to subsoil on same side of trench (Figure 4.6) with ditcher;

5. Topsoil from trench piled separately from subsoil on opposite side of trench (Figure 4.7) with ditcher; and

6. Topsoil and subsoil removed and replaced immediately by scraper on completed part of line. Minimal stockpiles needed (Figure 4.8).

Configurations numbered 3 and 5 above (Figures 4.5 and 4.7) provide the least opportunity for mixing topsoil and subsoil in the trench during backfilling.

Extra subsoil should be hauled away prior to spreading of topsoil in order to minimize mixing of topsoil and subsoil at the surface. Backfilling can be conducted with bulldozers, graders, backhoes, or a "Mormon board". The latter is shown schematically in Figure 4.2.

Compaction on the construction right-of-way can cause increased bulk densities and reduced permeability of topsoil and subsoil. Shields (1979) suggests that removal of topsoil over the construction right-of-way along with chisel plowing of compacted subsoil

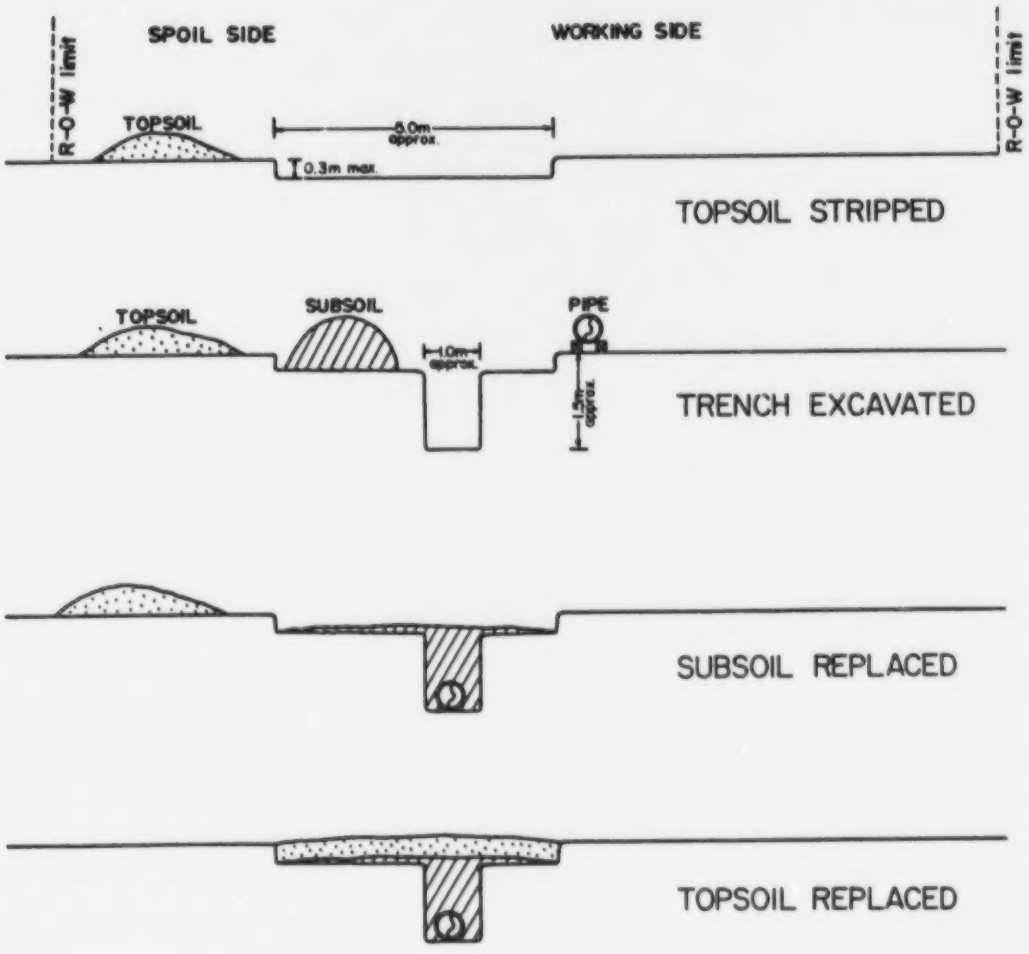


Figure 4.4
CONCEPTUAL DIAGRAM SHOWING THE TRENCH AND SUBSOIL PILE AREAS STRIPPED WITH BLADE. TOPSOIL AND SUBSOIL PILES WINDROWED ON SAME SIDE OF TRENCH.

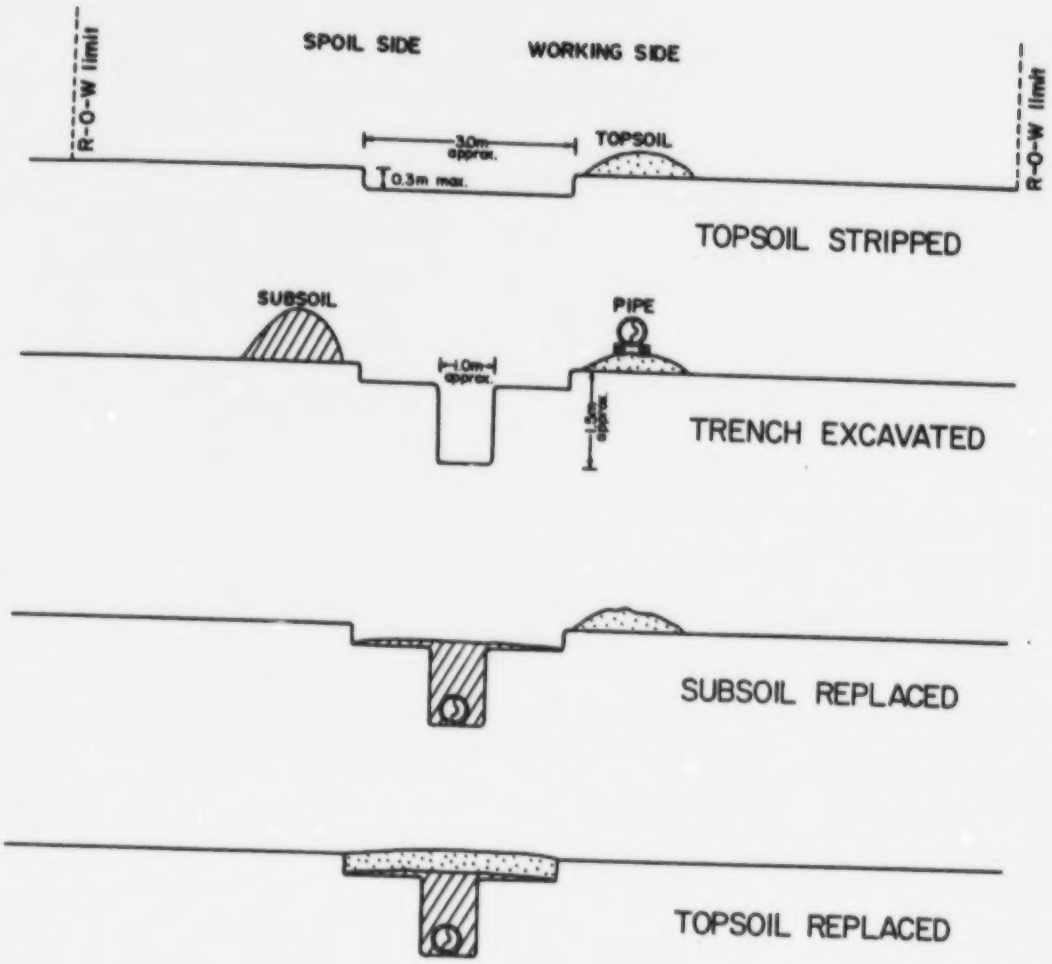


Figure 4.5
CONCEPTUAL DIAGRAM SHOWING THE TOPSOIL STRIPPED WITH BLADE. TOPSOIL AND SUBSOIL PILES WINDROWED ON OPPOSITE SIDES OF TRENCH.

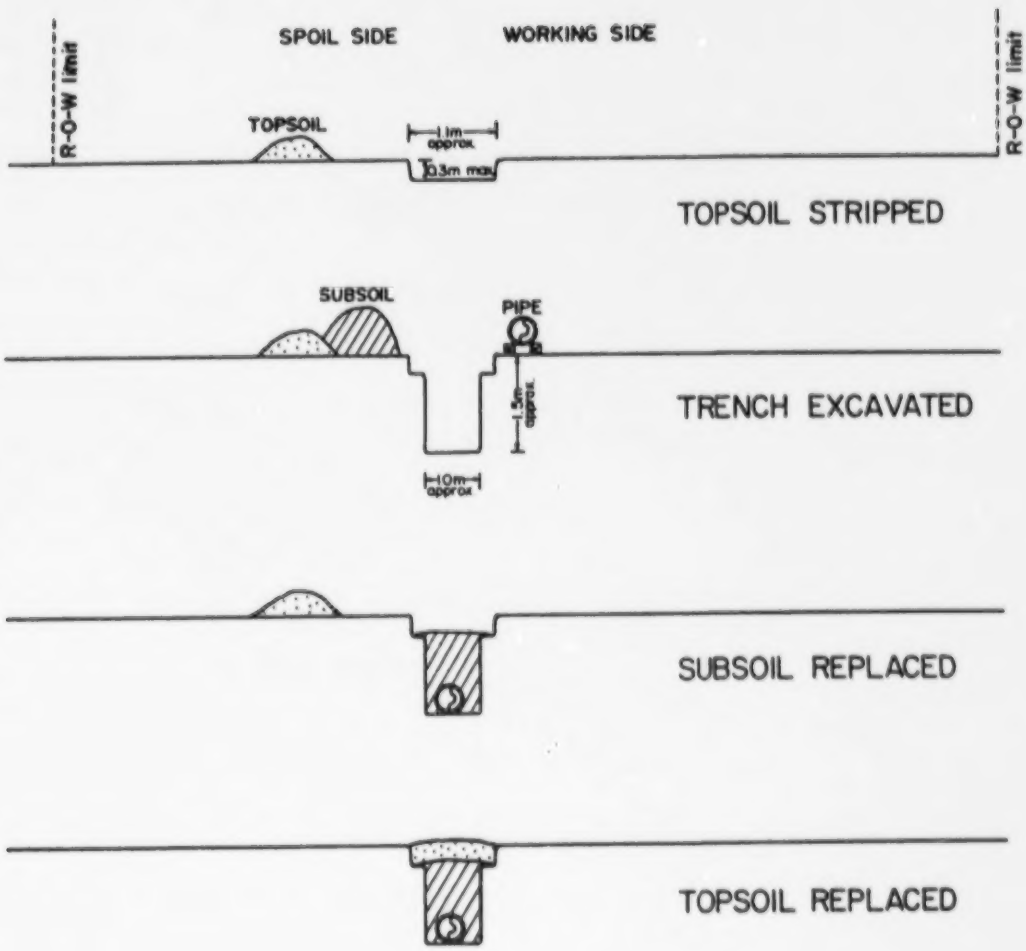


Figure 4.6
CONCEPTUAL DIAGRAM SHOWING THE TRENCH AREA STRIPPED WITH DITCHER TOPSOIL AND SUBSOIL PILES WINDROWED ON SAME SIDE OF TRENCH.

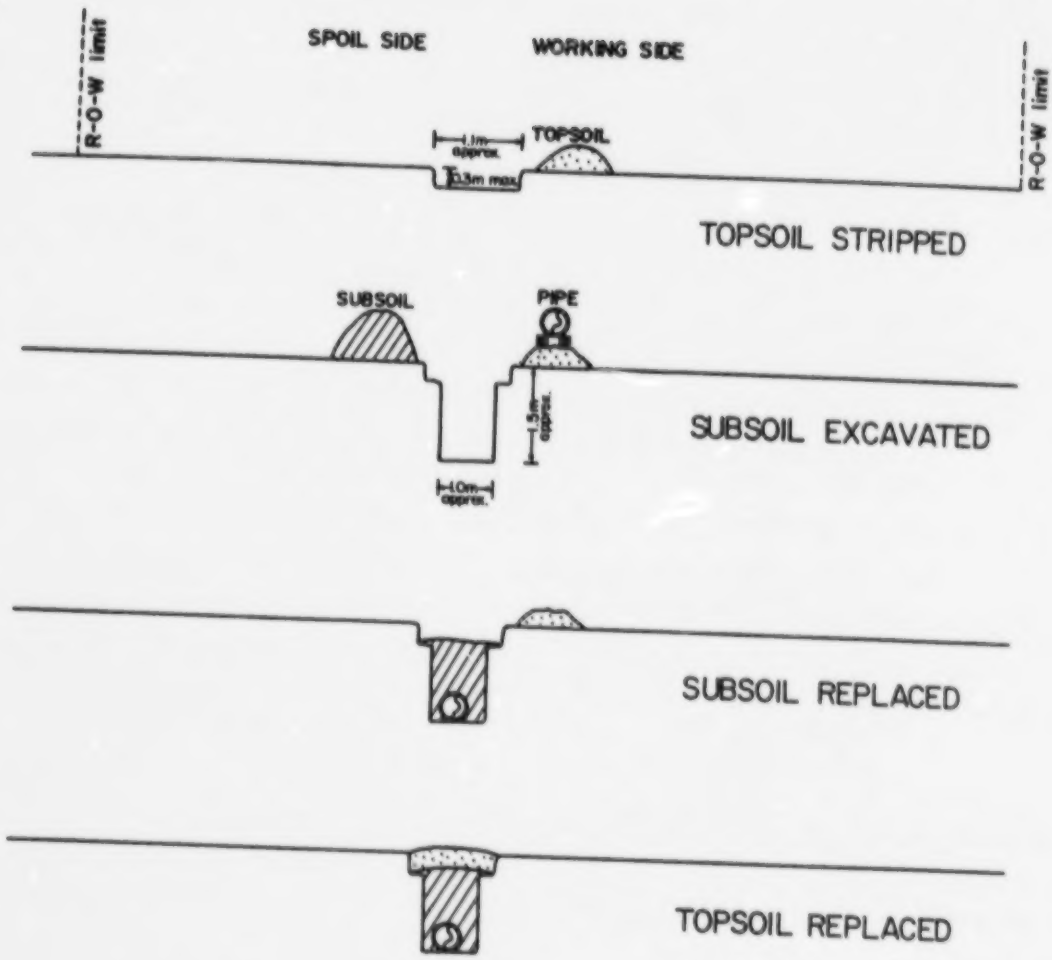


Figure 4.7
CONCEPTUAL DIAGRAM SHOWING THE TOPSOIL STRIPPED WITH DITCHER. TOPSOIL AND SUBSOIL PILES WINDROWED ON OPPOSITE SIDES OF TRENCH.

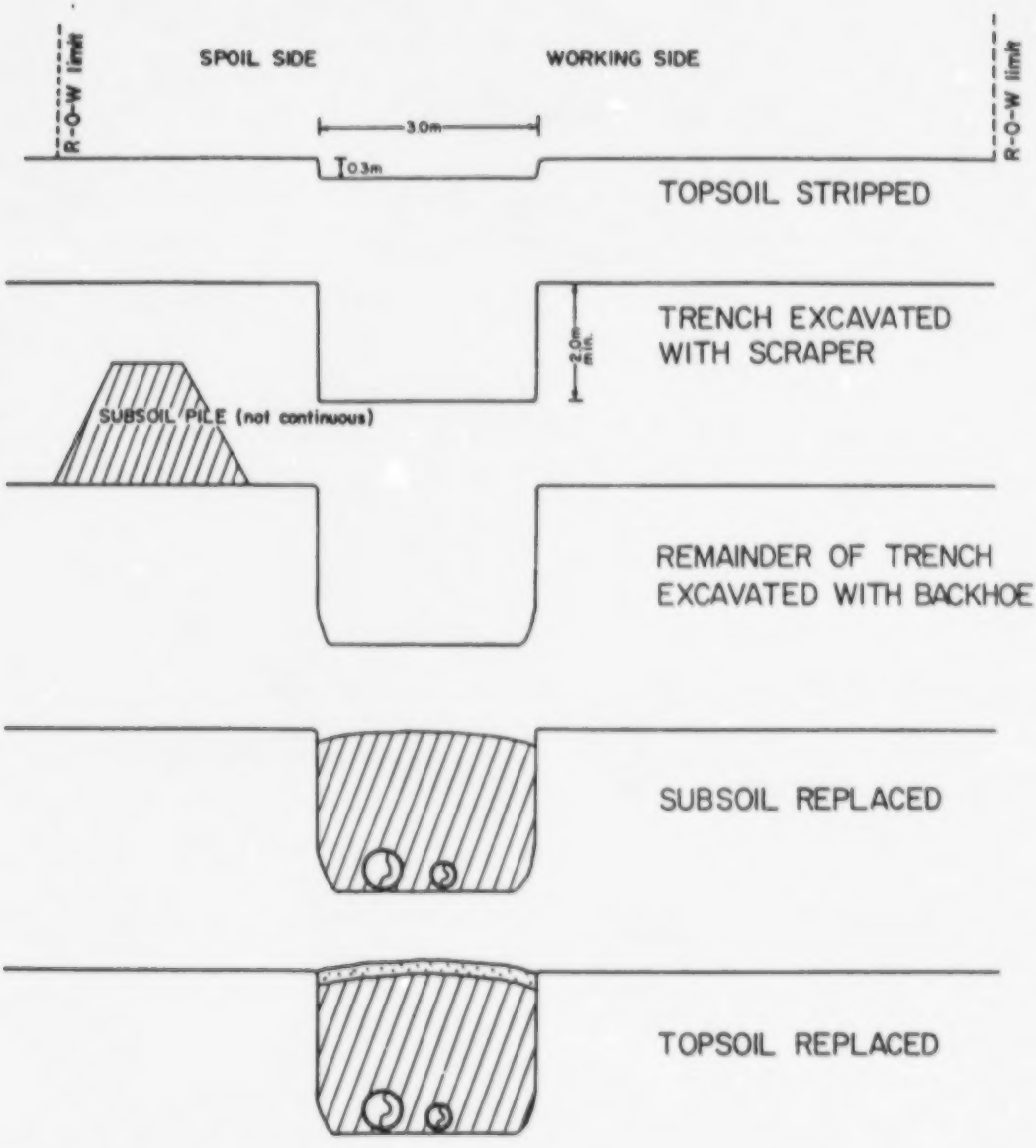


Figure 4.8
CONCEPTUAL DIAGRAM SHOWING THE METHOD USED FOR CONSTRUCTION OF A PARTICULAR WATER PIPELINE. TOPSOIL AND SUBSOIL STRIPPED WITH SCRAPER AND USED IMMEDIATELY FOR BACKFILLING OR PLACED IN SMALL PILES ON SPOIL SIDE OF TRENCH.

before replacement of topsoil will avoid most of the detrimental effects of compaction and rutting. Increased bulk densities can also be avoided by limiting construction during wet periods when soils are most susceptible to compaction.

Cook et al. (1974) indicates that topsoil should be evenly applied at a minimum depth of 15-20 cm over suitable subsoil so that a plant growth medium of at least 45 cm is provided. This is to ensure that adequate storage of moisture received in fall and winter is achieved. Power (1978) concludes that there is no advantage in providing a topsoil cover deeper than 75 cm over mine spoils. Mixing subsoil and topsoil merely diluted the topsoil effect.

Contour plowing of slopes greater than 5 percent and installation of erosion control measures are suggested for agricultural crop and pasture land. It is recommended that land be left in a roughened state, both to minimize surface crusting and to provide an adequate seedbed for germination and seedling growth (Hardy Associates 1981a).

Revegetation of cropland is normally left up to the landowner while pasture land may be reseeded to a grass mix such as the one in Table 4.3. Fertilizer is applied following soil test recommendations or in their absence, at a general rate (40 kg N and 50 kg P/ha). Seed and fertilizer are generally applied by dry broadcast immediately after construction, or in the spring, following construction (Hardy Associates 1981a).

Table 4.3. A general seed mix[1] suitable for mesic to xeric areas in parts of Alberta.

Species	Variety	Percent of Mix	kg/ha	lb/ac	Features and Tolerances
Grasses					
Canada bluegrass	Reubens (or Common)	10	3.0	2.5	no maintenance, grazing resistance, aggressive
Creeping red fescue	Boreal	30	9.0	7.5	palatable, good seedling vigor
Slender wheatgrass	Revenue	20	6.0	5.0	strong root system for erosion control
Crested wheatgrass	Fairway	10	3.0	2.5	good seedling vigor, can withstand traffic, not too tall
Timothy	Climax	10	3.0	2.5	quick establishing, fibrous roots
Smooth brome	Carlton	10	3.0	2.5	long lived, high yields
Legumes					
Clover	White Dutch	10	3.0	2.5	widely adapted
	BROADCAST APPLICATION RATE:		30	25	

1 From Hardy Associates (1978) Ltd. 1981a.

4.1.3.3 Wind Eroded Soils

Sandy, rapidly drained soils, from which natural vegetation has been removed, are most susceptible to wind erosion. Normally, if natural vegetation is not disturbed, soil moisture contents are higher, wind speed is reduced at the surface and wind erosion is not a problem. Sand dune vegetation is easily damaged by grazing or human activities, and therefore these areas are vulnerable to wind erosion. Trenching of sandy soils removes natural vegetation and can cause severe erosion problems unless prompt revegetation takes place. Wind erosion of sandy soils is not necessarily restricted to exposed areas since shifting sand may involve adjacent areas and may adversely affect vegetation cover off the right-of-way.

The first step in reclamation of wind eroded areas is to reduce sand movement. Lathe snow fences are the most common mechanical barrier, while wood fibre, asphalt, oil, manure, sludge, hay and straw mulches have also been used to stabilize sand. Once sand is stabilized, preparation of topography by rounding sharp ridges and reducing steep slopes should be undertaken prior to seeding.

Once soil drifting is reduced, vegetation must be established as soon as possible to stabilize sand permanently and accumulate organic matter and nutrients. Often grass and legume seed are included in the mulches (hydroseeding) so that revegetation can occur as quickly as possible. Seed may also be planted using a drill or broadcast seeder, after which a mulch is applied. Nova, An Alberta Corporation, is currently testing the effectiveness of equipment (Hodder gouger) which

leaves dish shaped depressions in the surface to improve the microtopography and surface moisture conditions for seed germination (Ken Wallace pers. comm. 1981).

Grass species found to be useful for revegetation of wind eroded sand in central Alberta include Russian wildrye (Elymus junceus), crested wheatgrass variety Nordan (Agropyron desertorum), pubescent wheatgrass (Agropyron trichophorum), Tall fescue (Festuca arundinacea), crested wheatgrass variety Fairway (Agropyron cristatum) and perennial rye grass (Lolium perenne). Sainfoin (Onobrychis viciaefolia) is a legume which has been effective in grass-legume mixes used to revegetate sand dunes (Lesko 1974). Transplanted clumps of native sod (hairy wild rye (Elymus innovatus)) have been used with success, however the cost of such a treatment is expensive. Seeding with cereal species such as Kodiak fall rye (Secale cereale) have been suggested as possible cover crops for Fairway crested wheatgrass and Russian wild rye (Hardy Associates 1980).

Lesko (1974) recommends early spring seeding to utilize water supplies from snow melt as well as hydromulching after seeding to prevent seed drift. Fertilizers are also necessary during the first two or three years of revegetation because nutrient levels are low in wind eroded sand.

4.1.3.4 Saline Soils

Salinity problems can occur if pipeline trenching operations bring saline parent material to the surface where it is mixed with topsoil. Information in the preceeding sections indicated that short term increases in salinity to levels as high as 4 mmhos/cm have been

detected. Since salinity levels above 4 mmhos/cm can affect production of certain crops (Table 4.4), additional reclamation measures may be necessary in trenching operations on saline soils. These may include addition of manure and organic matter to improve soil tilth, the use of salt tolerant crops (Table 4.4), or removal of saline soil and replacement with non-saline topsoil.

4.1.3.5 Sodic Soils

Thirty percent of the arable land in Alberta, 4.0 million hectares, is in the Solonetzic Order (Peters 1978). As a result, sodic Solonetzic soils will be frequently encountered in pipeline trenching operations.

Section 4.1.2 discusses the beneficial effects of trenching on soil structure and crop yield on Solonetzic soils. Mixing of the A, B and C horizons brings calcium and magnesium salts to the surface, displacing sodium, increasing pH and improving soil structure, all of which are beneficial to crop production. However, if sodium sulphate is brought to the surface adverse changes in soil structure may occur. Normally, since beneficial effects outweigh detrimental effects, little is done to anticipate or alleviate potential problems. Trenching should thoroughly mix the A, B and C horizons to a minimum depth defined by the calcium accumulation layer in the soil profile. Any shallower excavation may bring the Bnt horizon to the surface without any improvement in soil structure.

The mixing of nonsodic A, B and C horizons in trenched pipelines on Solonetzic soils should be beneficial. However, Krogman and McKay (1980) suggest that replacement of the A horizon over mixed

Table 4.4. Tolerance of crops for salts from the seedling stage onward (Sommerfeldt and Rapp 1977).

Low Tolerance (0-4 mmhos/cm)	Moderate Tolerance (4-8 mmhos/cm)	High Tolerance (8-15 mmhos/cm)
Field Crops		
field beans	sunflowers	barley
soybeans	flax	rape
peas	corn (field)	sugar beets
	wheat	
	oats	
	rye	
	winter wheat	
	sorghum	
Forage Crops		
red clover	alfalfa	tall wheatgrass
white dutch clover	orchardgrass	tall fescue
alsike clover	bromegrass	slender wheatgrass
timothy	reed canarygrass	Russian wild ryegrass
redtop	pubescent wheatgrass	altai wild ryegrass
		birdsfoot trefoil
		sweet clover
		crested wheatgrass

B and C horizons would provide both the advantage of high quality topsoil and improved soil structure below the topsoil for soils that are moderately saline or sodic. Most Ap horizons in Solonetzic soils are acidic in nature with some, such as Duagh loam, being moderately acidic (pH 5.1 to 5.5). Mixing of the Cca layer with acid A horizons increases pH and improves conditions for crop growth. The decision to save the A horizon should depend on the acidity of the A horizon and the salinity or sodicity of B and C horizons. Beneficial effects from increased pH of the A horizon, due to mixing, may be overshadowed by adverse effects due to an increase in sodium, salts or the dilution of nutrients and organic matter in the topsoil.

Coal mine reclamation procedures in Solonetzic soils involve stockpiling topsoil before stripping of overburden and replacement after completion of mining. Power et al. (1975) indicate that the addition of even 5 cm of topsoil appears to produce benefits greatly out of proportion to the amount used. S.A.R. of topsoil applied to sodic material remained low though migration of Na did occur, but only into the first 10 cm of topsoil. Separate stockpiling and replacement of topsoil on Solonetzic soils may reduce the S.A.R. at the soil surface. Increasing the thickness of topsoil or nonsodic material placed over sodic parent material retards the migration of Na into topsoil though Power (1978) concluded that there is no advantage in providing a topsoil cover deeper than 75 cm.

Chemical amendments such as lime and gypsum have been applied to Solonetzic soils to ameliorate physical and chemical properties. In combination with deep tillage (chiselling and deep plowing), Alzubaidi and Webster (1982) concluded that lime and gypsum lowered the

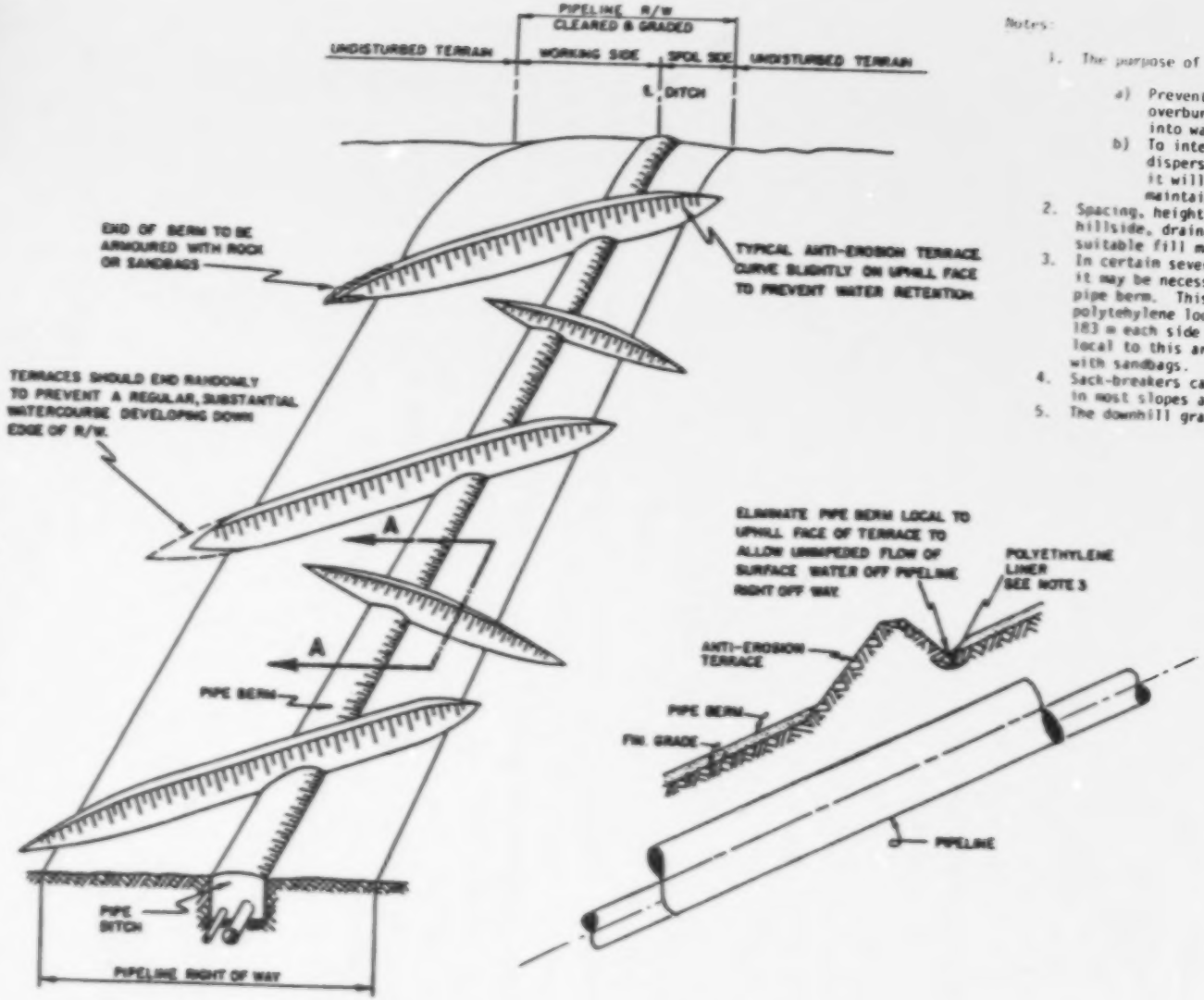
exchangeable sodium percentage in A and Bnt horizons of soil which had been chiselled. No significant changes in deep plowed and chemical treatments or normal tillage and chemical treatments were found. Pipeline reclamation methods have generally not included the addition of calcium in any form, although this practice may be beneficial in areas with acid Ap horizons or high S.A.R. values (15 or greater).

Mulches such as hay, straw or plant residue had little affect on sodic parent materials in the study by Power et al. (1975). Forages did improve soil structure in Solonetzic soils. Addition of mulches may have beneficial effects on Solonetzic soils in pipeline trenches.

4.1.3.6 Water Eroded Soils

Drainage measures are undertaken to ensure that no water impoundment or erosion occurs along the pipeline trench. Straw mulching and contour plowing are techniques employed on soils with slopes greater than 5 percent. For slopes greater than 20 percent shallow diversion terraces (Figure 4.9) are established to reduce water flow along the trench. The use of woodfibre mulches (1800 kg/ha), jute matting and plant gum binder as soil stabilizers to assist revegetation is suggested on high risk slopes (Midwest Research Institute 1975, Hardy Associates 1981b).

Revegetation using a seed mix such as presented in Table 4.3 is common practice to minimize water erosion. Annual rye is sometimes included for steeper slopes to provide cover while the grasses are establishing. Cropland is generally not revegetated using these techniques unless water erosion becomes a problem along the pipeline.


PIPELINE R/W
CLEARED & GRADED
UNDISTURBED TERRAIN
WORKING SIDE
SPOIL SIDE
UNDISTURBED TERRAIN
℄ DITCH
END OF BERM TO BE ARMOURED WITH ROCK OR SANDBAGS
TYPICAL ANTI-EROSION TERRACE CURVE SLIGHTLY ON UPHILL FACE TO PREVENT WATER RETENTION
TERRACES SHOULD END RANDOMLY TO PREVENT A REGULAR, SUBSTANTIAL WATERCOURSE DEVELOPING DOWN EDGE OF R/W.
A
A
PIPE BERM
PIPE DITCH
PIPELINE RIGHT OF WAY
PLAN
ELIMINATE PIPE BERM LOCAL TO UPHILL FACE OF TERRACE TO ALLOW UNIMPEDED FLOW OF SURFACE WATER OFF PIPELINE RIGHT OFF WAY
POLYETHYLENE LINER SEE NOTE 3
ANTI-EROSION TERRACE
PIPE BERM
FIN. GRADE
PIPELINE
SECTION A-A

Notes:

1. The purpose of anti-erosion terraces is to:
   a) Prevent surface run-off water from carrying the disturbed overburden from the pipeline construction down the hillside into watercourses causing increased siltation.
   b) To intercept and slow the velocity of the run-off water and disperse it into the surrounding undisturbed terrain where it will merge with the natural drainage of the hillside and maintain slope integrity of the right of way.
2. Spacing, height and mass of the terraces is based on steepness of hillside, drainage potential of the area and availibility of suitable fill material.
3. In certain severe cases of high volume/velocity of surface drainage, it may be necessary to armour the upstream terraces local to the pipe berm. This can be done by burying a sheet of 4-6 mil. polytehylene located 152 mm to 229 mm below surface and extended 183 m each side of pipeline. The surface should be protected local to this area by armouring with rock, timber or earth filled with sandbags.
4. Sack-breakers can be used in close conjunction with terracing in most slopes and hillsides.
5. The downhill gradient of the terraces should be approximately 3^{0}.

Figure 4.9

TYPICAL HERRINGBONE EROSION CONTROL TERRACING OF SLOPES

4.2 Summary of Field Data

Soil and vegetation characteristics were observed across the right-of-way at a total of 154 sites distributed throughout the agricultural areas of the province. The general areas where sites were located is shown relative to soil zone in Figure 4.10. The distribution of sites relative to soil zone, soil type, and farm practice, is summarized in Table 4.5. Legal locations for the sites are presented in Appendix F.

4.2.1 Gray Luvisolic Soil Zone/Peace River District

A total of 24 sites were examined in the Gray Luvisolic Soil Zone including the Peace River Region. Of the 24 sites, 19 were on Orthic Gray Luvisols, 3 were on Solonetzic Gray Luvisols, 1 on a Gray Solod and 1 on a Dark Gray Chernozemic soil. Fourteen of the sites were on annually cropped land and ten were under pasture. The pipelines at these sites varied from 1 to 19 years old and from 203.2 mm to 1219 mm diameter.

While the topsoil of the Solonetzic soil types may have similar characteristics to the Luvisols in the same zone, they are addressed separately in the following sections because of their characteristic subsoil properties. The Solonetzic soils have formed on parent material with higher sodium content than Luvisols. The presence of relatively high proportions of soluble and/or exchangeable sodium in the soil B and C horizons results in physical and chemical characteristics which can affect plant growth. The effects of disturbance during pipeline construction and reclamation could consequently be different from the effects in Luvisols.

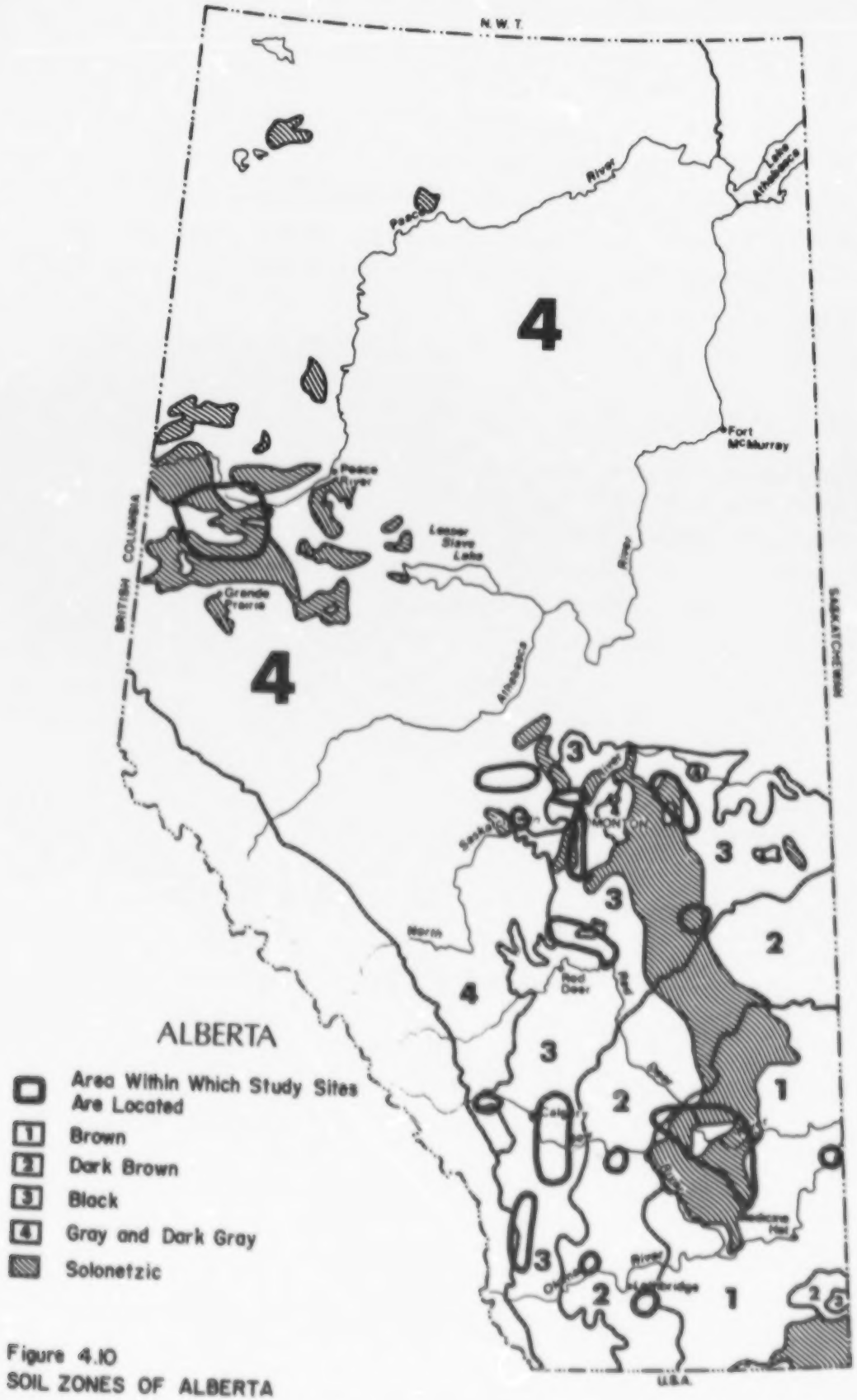


Figure 4.10
SOIL ZONES OF ALBERTA

Table 4.5. Summary of sites evaluated.

Gray Soil Zone	Gray Luvisolic	Solonetzic	Total
Annual Crops	11	3	14
Improved Pasture	5	1	6
Native Pasture	4	0	4
Total	20	4	24

Pipeline Age Range: 1 to 19 years old
Pipeline Size Range: 203.2 to 1219 mm

Black Soil Zone	Chernozemic	Solonetzic	Total
Annual Crops	23	9	32
Improved Pasture	13	6	19
Native Pasture	9	0	9
Total	45	15	60

Pipeline Age Range: 1 to 69 years old
Pipeline Size Range: 203.2 to 1219 mm

Table 4.5. (Continued)

Dark Brown Soil Zone	Chernozemic	Solonetzic	Total
Annual Crops			
- Total	9	0	9
- Dry Land	(8)	(0)	(8)
- Irrigated	(1)	(0)	(1)
Improved Pasture	5	4	9
Native pasture	4	0	4
Total	18	4	22

Pipeline Age Range: 3 to 23 years old
Pipeline Size Range: 76.2 to 863.6 mm

Brown Soil Zone	Chernozemic	Solonetzic	Total
Annual Crops			
- Total	7	9	16
- Dryland	(4)	(9)	(13)
- Irrigated	(3)	(0)	(3)
Improved Pasture			
- Total	7	0	7
- Dryland	(4)	(0)	(4)
- Irrigated	(3)	(0)	(3)
Native Pasture	10	15	25
Total	24	24	48

Pipeline Age Range: 2 to 24 years old
Pipeline Size Range: 254 to 1067 mm

Table 4.5. (Continued)

All Soil Zones	Luvisolic/ Chernozemic	Solonetzic	Total
Annual Crops			
- Total	50	21	71
- Dryland	(46)	(21)	(67)
- Irrigated	(4)	(0)	(4)
Improved Pasture			
- Total	30	11	41
- Dryland	(27)	(11)	(45)
- Irrigated	(3)	(0)	(3)
Native pasture	27	15	42
Total	107	47	154
Pipeline Age Range:	1 to 69 years old		
Pipeline Size Range:	76.2 to 1219 mm		

4.2.1.1 Gray Luvisolic Soils

Table 4.6 presents the results for the sites in the Gray Luvisolic Soil Zone/Peace River District. Soil type and texture, crop and pipeline characteristics are summarized for each site. Sites are listed by age for Luvisolic soils with annual and pasture crops followed by Solonetzic soils.

Effects on Soil

Topsoil was found to be thoroughly mixed with soil parent material (C horizon) or absent on the trench surfaces at 40 percent of the non-Solonetzic sites in the Gray Soil Zone. This was indicated at various sites by differences in color from undisturbed topsoil reflecting loss or dilution of organic matter, presence of carbonates, and/or changes in soil texture and structure. Mixing of the topsoil with only the B horizon was found over the trench at 45 percent of the sites. Such mixing was indicated by changes in color and texture. Often clods of B horizon material with finer texture and characteristic blocky structure were clearly visible in the mixed topsoil layer. Carbonates were not evident in this case. Only 15 percent of the sites had minimal or no mixing of topsoil with lower soil layers. The topsoil over the trenches at these latter sites was similar in color, texture, structure and consistance to the adjacent off right-of-way topsoil.

The results were similar on the stockpile areas with 45 percent sites having no topsoil or thoroughly mixed topsoil and

Table 4.6. Summary of results showing changes in soil and vegetation on pipeline rights-of-way in the Gray Soil Zone/

				Pipeline			Topsoil Mixed[2]			Vegetation Trench Area		
Site	Soil Type	Texture	Crop	Age[1] (Season)	Size (mm)	Topsoil Salvaged	Trench Area	Stockpile Area	Working Area	Live Cover	Height	Head
76A	Dark Gray Luvisol	fine	barley	7-1 (w)		all r.o.w.	Y	Y	Y	-81	-18	MD
76b	Dark Gray Luvisol	fine	barley	1 (w)	1219	all r.o.w.	Y	Y	Y	-81	-38	MD
77a	Orthic Gray Luvisol	fine	barley	7-1 (w)		all r.o.w.	Y	Y	Y	-78	-45	MD
77b	Orthic Gray Luvisol	fine	barley	1 (w)	1219	all r.o.w.	Y	Y	Y	-75	-41	MD
63	Dark Gray Chernozem	fine	wheat	2	508.0	all r.o.w.	A/B only	Y	Y	<10	<10	<10
84	Orthic Gray Luvisol	fine	wheat	4	406.4	on trench	A/B only	A/B only	A/B only	+82	+28	<10
74c	Orthic Gray Luvisol	coarse	oats	5 (s)		on trench	N	N	N	<10	<10	MD
82	Orthic Gray Luvisol	fine	barley	9 (s)	508.0	on trench	A/B only	A/B only	N	<10	+26	+18
74d	Orthic Gray Luvisol	coarse	oats	12 (s)	508.0	on trench	A/B only	A/B only	A/B only	<10	+18	MD
74a	Orthic Gray Luvisol	coarse	oats	19 (s)	304.8	on trench	A/B only	A/B only	N	<10	<10	MD
74b	Orthic Gray Luvisol	coarse	oats	19 (s)	304.8	on trench	A/B only	A/B only	A/B only	<10	<10	MD
88	Orthic Gray Luvisol	fine	clover fescue	4	203.2	on trench	N	N	N	<10	MD	MD
75c	Orthic Gray Luvisol	fine	clover timothy	5 (s)		on trench	N	N	N	<10	<10	MD
78b	Orthic Gray Luvisol	fine	bush pasture	5 (s)		None	Y	Y	N	<10	MD	MD
75d	Orthic Gray Luvisol	fine	clover timothy	12 (s)	508.0	on trench	A/B only	A/B only	A/B only	<10	-37	MD
78a	Orthic Gray Luvisol	fine	bush pasture	12 (s)	508.0	None	Y	Y	N	<10	MD	MD

Peace River Region.

(Percent Difference from Controls[3])

Stockpile Area			Working Area					Change in Topsoil Consistence[4]			
Live Cover	Height	Head	Live Cover	Height	Head	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
-95	-41	ND	-81	-21	ND	None	No	-	-	N	Mixed topsoil varies 7-15 cm deep. Crops tallest at 15 cm soil depth. Water line built in 1974; redisturbed in 1980.
-81	-21	ND	-81	-21	ND	None	No	-	-	N	Contoured drainage after topsoil replacement. Poor revegetation. Less weeds on right-of-way.
-65	-35	ND	-75	-41	ND	None	No	N	N	N	Less weeds. Topsoil texture finer on right-of-way.
-75	-48	ND	-73	-48	ND	None	No	N	N	N	Less weeds. Topsoil texture finer on right-of-way.
-26	< 10	< 10	-26	< 10	< 10	None	No	N	N	N	Topsoil salvage includes A+B to 30 cm. Mixed with C on replacement.
+41	+24	< 10	-186	< 10	< 10	None	No	-	-	N	Crop slightly greener on trench.
10	< 10	ND	< 10	< 10	ND	None	No	N	N	N	Increased stinkweed.
-30	< 10	+11	< 10	< 10	< 10	None	Yes	N	N	N	Increased Equisetum. Topsoil texture finer on trench.
< 10	< 10	ND	< 10	< 10	ND	None	No	N	N	N	Topsoil texture is loam on right-of-way, sandy loam on control.
< 10	< 10	ND	< 10	< 10	ND	None	No	N	N	+	Topsoil texture is loam on right-of-way, sandy loam on control.
< 10	< 10	ND	< 10	< 10	ND	None	No	N	N	N	Increased stinkweed. Loam on right-of-way. Sandy loam on control.
+54	ND	ND	+46	ND	ND	None	Yes	+	N	N	Stonier on trench.
< 10	-37	ND	< 10	< 10	ND	10-15 cm	Yes	N	N	N	Gopher/badger holes increased on trench. Stones picked.
< 10	ND	ND	< 10	ND	ND	None	Yes	N	N	N	15-20 cm mound of slash and soil on trench. Poplar, willow, aspen regeneration.
< 10	-25	ND	< 10	< 10	ND	10-15 cm	Yes	N	N	N	Gopher/badger holes increased on trench. Stones picked.
< 10	ND	ND	< 10	ND	ND	None	No	-	N	N	Cover reduced to 0 percent on right-of-way where grass cut and baled on dry knolls.

Table 4.6 (Continued)

Site	Soil Type	Texture	Crop	Pipeline Age[1] (Season)	Pipeline Size (mm)	Topsoil Salvaged	Topsoil Mixed[2] Trench Area	Topsoil Mixed[2] Stockpile Area	Topsoil Mixed[2] Working Area	Vegetation Trench Area Live Cover	Vegetation Trench Area Height	Vegetation Trench Area Head
75a	Orthic Gray Luvisol	fine	clover timothy	19 (s)	304.8	on trench	A/B only	A/B only	N	< 10	< 10	MD
75b	Orthic Gray Luvisol	fine	clover timothy	19 (s)	304.8	on trench	A/B only	A/B only	A/B only	< 10	-25	MD
78c	Orthic Gray Luvisol	fine	bush pasture	19 (s)	304.8	None	Y	Y	N	< 10	MD	MD
78d	Orthic Gray Luvisol	fine	bush pasture	19 (s)	304.8	None	Y	Y	N	< 10	MD	MD
85	Solonetzic Gray Luvisol	fine	barley	4	406.4	None	Y	Y	Y	< 10	< 10	< 10
86	Solonetzic Gray Luvisol	fine	barley	4	406.4	None	Y	Y	Y	-53	< 10	< 10
87	Solonetzic Gray Luvisol	fine	alfalfa clover	4	406.4	on trench	A/B only	A/B only	Y	< 10	+20	MD
93	Gray Solod	fine	canola	9 (s)	508.0	on trench	N	N	N	< 10	+55	MD

1
(w) - winter construction
(s) - summer construction

2
A/B only - only A and B soil horizon mixed
Y - topsoil mixed with subsoil (C horizon) or topsoil absent
N - topsoil not mixed

3
+ - percentage higher than controls
- - percentage lower than controls
MD - no data

4
N - no change from control soils
- - firmer consistence than control soils
+ - looser

(Percent Difference from Controls[3])

Stockpile Area			Working Area					Change in Topsoil Consistence[4]			
Live Cover	Height	Head	Live Cover	Height	Head	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
<10	≤10	ND	<10	+25	ND	10-15 cm	Yes	N	N	N	Increased Canada thistle on trench.
<10	-37	ND	<10	<10	ND	10-15 cm	Yes	N	N	N	Gopher/badger holes increased on trench. Stones picked.
<10	ND	ND	<10	ND	ND	None	No	N	N	N	Native grass and shrubs predominant.
<10	ND	ND	<10	ND	ND	None	No	N	N	N	Native grass and shrubs predominant.
-65	<10	+15	-79	<10	<10	None	No	-	N	N	Shaly Csk horison left on surface of trench working and stockpile areas.
-82	-11	10	-65	<10	<10	None	No	N	N	N	5-10 cm layer mixed A and Csk over all right-of-way. Increased weeds on trench.
-64	-30	ND	-19	-12	ND	None	No	N	-	-	Mixed topsoil shallower on all right-of-way. Increased dandelion on all right-of-way.
<10	+30	ND	<10	+19	ND	None	No	-	N	N	Somewhat less stinkweed than control. Minimum topsoil depth is 10 cm on trench.

C horizon material, 40 percent of the sites with mixed topsoil and B horizon material and 15 percent of the sites where the topsoil on the surface was not mixed.

Over the working areas, the topsoil was thoroughly mixed with C horizon material at 25 percent of the sites and mixed with B horizon material at 25 percent of the sites. Generally, where topsoil had been stripped from the trench, stockpile and working areas prior to trenching, topsoil was mixed with C horizon. Most of these sites were on water pipeline rights-of-way.

The depth of mixed or unmixed topsoil found on the rights-of-way varied from 7 to 30 cm, compared to a range of 10 to 27 cm for control soils. Only one site had no topsoil layer (mixed or unmixed) over the trench. This occurred on a 10 year old bush pasture site (78d).

Trench settlement was evident at 20 percent of the sites. Settlement was generally 10 to 15 cm in fine textured Orthic Gray Luvisols with a clover/timothy pasture crop. This settlement was found on 4, 5, 12 and 19 year old sites with pipelines from 304.8 to 508 mm in diameter. They were constructed in summer under dry to moist soil conditions. A mound was found in one trench in bush pasture where slash was mixed with topsoil and replaced. Surface stoniness increased at 35 percent of the sites and usually over the trench area only. On at least 4 of these sites, stones were picked during reclamation and by the farmer the following year. Nevertheless, an increase in surface stoniness was still evident. The increase was in the order of one class (CSSC 1978, p. 128) either from slightly to moderately or moderately to very stony.

Effects on Vegetation

At 75 percent of the sites, the estimated live vegetation cover over the trench varied less than 10 percent from adjacent control areas. One site had an 82 percent increase in cover of wheat (site 84) over the trench while four sites had reduced cover of barley and weeds over the trench in the first growing season following construction. Forty percent of the sites where plant height was recorded had reduced plant height (18 to 45 percent lower than controls) over the trench while 20 percent of the sites showed increases from 18 to 28 percent.

A similar trend was evident in crop cover and height over stockpile and working areas of the rights-of-way.

Decreases in percent live cover and/or crop height appear to be the result of one or more of the following conditions:

- extensive mixing of topsoil with B horizon and/or parent material (C horizon);
- shallow topsoil replacement depth;
- loss of topsoil on contouring of drainageways; and
- cracking and crusting in areas of water ponding.

At site 82, the reasons for decreased growth over the stockpile area were not apparent. Such is also the case for sites 75b, c and d, although the nonuniform distribution of species in the seeded grass/legume mixture could be a cause.

Characteristics of sites that experienced decreases in vegetation are further expanded in Appendix A.

Increases or little change in percent live cover and/or plant height occurred on Gray Luvisolic soils over pipelines greater than four years old with the following general conditions:

- topsoil unmixed or mixed with B horizon only;
- crops are barley, oats, wheat or forage; and
- generally no trench settlement or compaction on working or stockpile areas.

4.2.1.2 Gray Solonetzic Soils

Four sites in the Gray Soil Zone are on soils with Solonetzic characteristics (Table 4.6). All are fine textured; crops include barley, alfalfa/clover and canola.

Effects on Soil

One of the four sites (85) was found to have a saline parent material (Csk horizon) on the surface of the trench and a 3 cm layer of the same material above the topsoil on the stockpile area. Topsoil on the working area surface at this site was unmixed. Site 86 was found to have a topsoil and subsoil (Csk horizon) mixture 5 to 10 cm deep over the surface of the trench, stockpile area and working area. Except on the trench, this layer covered the original topsoil layer. At site 87, the 10 cm layer of topsoil over the trench and stockpile area had some B horizon material mixed with it. The top 10 cm of topsoil on the working area had some parent material (Csk horizon) mixed into it. The

topsoil layer over B horizon material in the stockpile area was 15 cm deep compared to the adjacent control soil topsoil depth of 25 cm. The topsoil at site 83 was not mixed at any location on the right-of-way and had a similar depth of 10 to 15 cm as the control soil at that site.

Trench settlement, mounding or increased surface stoniness were not evident at any of the four sites.

Effects on Vegetation

At three of the four sites, live vegetation cover over the trench varied less than 10 percent from adjacent control areas. Site 86 showed a 53 percent decrease in barley cover over the trench. The 406.4 mm gas pipeline at this site is 4 years old. Vegetation height over the trench at two of the four sites varied less than 10 percent from that of the control areas. Twenty and 55 percent increases in height were found over the trench at these two sites.

Large decreases in cover (64 to 82 percent) and height (less than 10 to 20 percent) were found over the stockpile areas of three of the four sites. The fourth site (83) was found to have similar cover and a 30 percent increase in height compared to controls. This site had topsoil salvaged over the trench and there was no evidence of mixing of topsoil on the trench, stockpile area or working area. Site 83 showed a similar trend in the working area with less than 10 percent difference in cover and a 19 percent increase in height of the canola crop. The other three sites showed a decrease in cover from 19 to 79 percent over the working area. Plant height showed a decrease of 12 percent at site 87 and varied less than 10 percent from controls at sites 85 and 86.

Decreases in percent live cover or crop height occurring at three of the four Solonetzic sites in the Gray Soil Zone appear to be caused by:

- a layer of saline parent material left on the surface; and
- mixing of saline parent material with topsoil.

Characteristics of sites that experienced decreases in vegetation are further expanded in Appendix A.

Increases or little change in percent live cover and/or plant height occurred on Solonetzic sites in the Gray Soil Zone with the following general characteristics:

- cultivated annually or seeded to forage crops;
- replaced topsoil not mixed; and
- no subsoil (B or C horizon) left on working or stockpile areas.

Where topsoil is mixed with B or C horizon materials of Solonetzic soils, or if subsoil is left on the surface, increases or little change in cover or height may occur in the trench area only.

4.2.2 Black Soil Zone

A total of 60 sites were examined in the Black Soil Zone. Of these sites, 45 were on Black Chernozemic soils (22 were under pasture and 23 annually cropped) and 15 were on Black Solonetzic soils (6 under pasture and 9 annually cropped). The pipelines at these sites varied from 1 to 69 years old and from 203.2 mm to 1067 mm in diameter.

4.2.2.1 Black Chernozemic Soils

Tables 4.7 and 4.8 summarize the results for the study sites in the Black Soil Zone. Table 4.7 shows the soil and vegetation characteristics for sites with Chernozemic or Solonetzic soils under annual cultivation. Table 4.8 summarizes the results for sites with Chernozemic or Solonetzic soils under forage cropping.

Effects on Soil

Topsoil was observed to be thoroughly mixed or absent on the trench surfaces at 82 percent of the sites with Chernozemic soil, while no mixing was observed over the trench at 16 percent of the sites. Mixing of the A and B horizons only occurred at one site. The evidence for mixing was similar to that in the Gray Soil Zone (i.e., presence of carbonates, and changes in color, texture and/or structure).

Topsoil mixing was only slightly less common over the stockpile areas with 67 percent of the sites observed to be thoroughly mixed. No mixing occurred on stockpile areas at 24 percent of the sites. Mixing of A and B horizons only, was observed at 9 percent of the sites.

Less than half of the 45 working areas had topsoil mixing, while 55 percent of the sites had no mixing. One site was observed where only A and B horizons were mixed.

The depth of mixed or unmixed topsoil found on the rights-of-way varied considerably from 5 to 65 cm compared to 13 to 33 cm on

Table 4.7. Summary of results showing changes in soil and vegetation on pipeline rights-of-way in the Black Soil Zone:

Site	Soil Type	Texture	Crop	Pipeline Age[1] (Season)	Pipeline Size (mm)	Topsoil Salvaged	Topsoil Mixed[2] Trench Area	Topsoil Mixed[2] Stockpile Area	Topsoil Mixed[2] Working Area	Vegetation Trench Area Live Cover	Vegetation Trench Area Height	Vegetation Trench Area Weed
45	Orthic Black Chernozem	coarse	barley	1 (u)	203.2	on trench	A/B only	Y	Y	< 10	< 10	< 10
52	Orthic Black Chernozem	coarse	barley	1 (u)	203.2	on trench	Y	Y	N	< 10	< 10	< 10
58	Orthic Black Chernozem	fine	barley	1 (u)	203.2	on trench	N	N	N	< 10	< 10	< 10
80	Orthic Black Chernozem	fine	barley	1 (u)		on trench	Y	Y	N	< 10	< 10	< 10
81	Orthic Black Chernozem	fine	barley	1 (u)		on trench	Y	Y	N	+29	+44	+21
57	Orthic Black Chernozem	fine	wheat	2 (u)	508.0	on trench and stockpile	Y	A/B only	A/B only	+71	+16	< 10
59	Orthic Black Chernozem	fine	wheat	2 (u)	508.0	A/B all t.o.w.	Y	Y	N	+88	< 10	< 10
8	Orthic Black Chernozem	fine	barley	3	304.8	on trench	Y	N	N	+13	+13	ND
5b	Orthic Black Chernozem	fine	barley	3		on trench	Y	N	N	< 10	+16	ND
70a	Calcareous Black Chernozem	fine	oats barley	4 (s)	609.6	on trench	Y	Y	Y	< 10	< 10	ND
71b	Orthic Black Chernozem	fine	barley	5 (s)		on trench	-	N	N	< 10	+11	< 10
18	Orthic Black Chernozem	fine	canola	5 (s)	406.4	all t.o.w.	Y	Y	Y	< 10	< 10	ND
19	Orthic Black Chernozem	fine	wheat	5 (s)	406.4	on trench	Y	N	N	< 10	< 10	ND
54a	Orthic Black Chernozem	fine	canola	6 (s)	406.4	on trench	N	Y	N	< 10	< 10	ND
49	Gleyed Black Chernozem	coarse	barley	11 (s)	254.0	on trench	N	N	N	+38	+13	< 10
66	Orthic Black Chernozem	fine	wheat	11 (s)	254.0	on trench	N	N	N	< 10	< 10	< 10

annually cropped land.

(Percent Difference from Controls[3])

Stockpile Area			Working Area					Change in Topsoil Consistence[4]			
Live Cover	Height	Head	Live Cover	Height	Head	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
<10	<10	<10	<10	<10	<10	None	No	-	-	S	Finer textured topsoil on trench and stockpile areas. 10-24 cm mixed topsoil layer replaced.
<10	<10	<10	<10	<10	<10	None	No	"	"	"	Finer textured topsoil on trench. 10-65 cm mixed topsoil placed on trench and stockpile areas.
<10	+10	+12	<10	+11	+11	None	No	"	+	"	Finer textured topsoil on trench. Stones picked. Settling backfilled. Topsoil 13-25 cm on right-of-way.
<10	<10	<10	<10	<10	<10	None	No	"	"	-	Slight compaction on working area. Replaced topsoil mixed. Topsoil 0-10 cm deep.
+20	+20	+10	+20	+23	<10	15-30 cm	No	"	"	"	Alternating /Ch/Ch layers 0-15 cm deep in trench. Topsoil 0-10 cm deep.
-45	-10	<10	-45	<10	<10	None	Yes	+	+	-	Texture finer on trench. Increased stones on trench.
<10	<10	<10	-45	<10	<10	None	No	"	"	"	Texture finer on trench. Mixed topsoil replaced 12-25 cm deep.
+13	+10	MD	+13	+10	MD	None	No	"	"	"	Replaced topsoil 10 cm. Mixed on trench. Some Canada thistle on working and stockpile areas.
+26	+30	MD	10	+27	MD	None	No	"	"	"	Replaced mixed topsoil on trench 40 cm deep. 19 cm topsoil on control.
<10	<10	MD	<10	<10	MD	None	No	"	"	"	Mixed topsoil replaced 12-18 cm deep. Control topsoil 33 cm deep.
<10	+10	<10	<10	+13	<10	None	No	"	"	"	Replaced topsoil 21-33 cm.
<10	<10	MD	<10	<10	MD	None	No	+	+	"	Topsoil stockpiled on working side. 20 cm topsoil stripped. 20 cm mixed topsoil replaced.
-24	<10	MD	-24	<10	MD	None	No	"	"	"	Replaced topsoil 10-15 cm. Less weeds on right-of-way.
<10	<10	MD	<10	<10	MD	None	No	"	"	"	Some subsoil mixed with topsoil on stockpile area.
<10	<10	<10	<10	<10	-11	None	No	"	"	"	Soil drier over trench. Effects due to heated pipe or better drainage.
<10	<10	<10	<10	<10	<10	None	No	"	"	"	Topsoil 13-17 cm on right-of-way. 15 cm on control.

Table 4.7 (Continued)

Site	Soil Type	Pasture	Crop	Pipeline Age[1] (Seasons)	Pipeline Size (mm)	Topsoil Salvaged	Topsoil Mixed[2] Trench Area	Topsoil Mixed[2] Stockpile Area	Topsoil Mixed[2] Working Area	Vegetation Trench Area Live Cover	Vegetation Trench Area Height	Vegetation Trench Area Bond
3	Orthic Black Chernozem	fine	barley	11 (s)	254.0	on trench	Y	N	N	≤ 10	≤ 10	MD
5a	Orthic Black Chernozem	fine	barley	15		None	Y	Y	N	+51	+55	MD
11a	Orthic Black Chernozem	fine	barley	19 (s)	324.0	on trench	Y	N	N	≤ 10	+16	≤ 10
5a	Orthic Black Chernozem	fine	barley	13	914.4	None	Y	Y	Y	-51	+53	MD
14b	Orthic Black Chernozem	fine	canola			None	Y	Y	N	≤ 10	-13	MD
10b	Calcareous Black Chernozem	fine	oats barley	(w)	323.7	None	Y	Y	Y	≤ 10	≤ 10	MD
10y	Calcareous Black Chernozem	fine	oats barley	(s)	324.0	None	Y	Y	Y	≤ 10	≤ 10	MD
60	Black Solodized Solonetz	fine	wheat	2 (w)	508.0	None	Y	Y	Y	-100	-100	MD
61	Black Solodized Solonetz	fine	oats	2 (w)	508.0	None	Y	Y	N	-69	-53	MD
64b	Black Solodized Solonetz	fine	oats	3 (s)		on trench	Y	Y	Y	≤ 10	-10	MD
11b	Black Solodized Solonetz	fine	barley	5 (s)		on trench	Y	Y	Y	+54	≤ 10	≤ 10
59a	Black Solod	fine	barley	6 (s)	406.4	on trench	N	N	N	≤ 10	-10	-11
3	Black Solodized Solonetz	fine	barley	11 (s)	324.7	on trench	Y	Y	Y	≤ 10	≤ 10	MD
64a	Black Solodized Solonetz	fine	oats	19 (s)	324.0	on trench	Y	N	N	≤ 10	≤ 10	MD
11a	Black Solodized Solonetz	fine	barley	19 (s)	324.0	None	Y	Y	N	+190	+18	≤ 10
55b	Black Solod	fine	barley			on trench	Y	N	N	+39	-35	-11

1 (w) - winter construction
(s) - summer construction

2 A/B only - only A and B soil horizon mixed
Y - topsoil mixed with subsoil (2 horizons or topsoil amount
N - topsoil not mixed

3 + - percentage higher than controls
- - percentage lower than controls
MD - no data

4 N - no change from control soils
+ - firmer consistence than control soils
- - looser

(Percent Difference from Concrete[1])

Stockpile Area			Working Area					Change in Topsoil Consistence[1]			
Live Cover	Height	Weed	Live Cover	Height	Weed	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
<10	< 10	HD	< 10	< 10	HD	None	No	0	0	-	Topsoil 15-19 cm on right-of-way, 11 cm on control. Working area slightly compacted.
+17	+35	HD	+26	+32	HD	None	No	0	0	0	Mixed topsoil on trench twice as deep as control.
<10	+16	< 10	< 10	+22	< 10	None	No	0	0	0	Unmixed topsoil buried below mixed A/C layer 10 cm deep. Texture finer over trench.
+17	+32	HD	+17	+35	HD	None	No	-	0	0	Large, very firm clods over trench in top 15 cm. Stinkweed more common.
< 10	< 10	HD	< 10	< 10	HD	None	No	0	0	0	Soil drier over trench. Loam texture.
< 10	< 10	HD	< 10	< 10	HD	None	No	+	0	0	A horizon buried by C/A layer 10-30 cm deep on stockpile and working area.
< 10	< 10	HD	< 10	< 10	HD	None	No	+	0	0	Farmer broke part of drill on loose soil over trench. A horizon buried by 20-35 cm A/C layer on stockpile and working area.
-100	-100	HD	-100	-100	HD	None	No	-	-	-	30 cm crown on trench. Crusting over all right-of-way. Salt visible. 60% cover weeds on stockpile and working area.
-53	-27	HD	< 10	-14	HD	10 cm	No	0	0	0	Lowest subsoil in trench. CSR (EC = 5.0-7.1 mS/cm) mixed with A on trench and stockpile areas. SAR 11.2-19.7.
< 10	-10	HD	< 10	< 10	HD	None	No	0	0	0	Drainage better in trench. Topsoil mixed and shallower than controls (20 cm vs. 31 cm).
+31	+10	< 10	+154	< 10	< 10	None	No	0	0	0	Growth more uniform on right-of-way than control. Mixed A/C layer 5-15 cm over right-of-way.
< 10	-15	< 10	< 10	-10	< 10	None	No	0	0	0	10 cm topsoil over C horizon in trench.
< 10	-10	HD	< 10	-10	HD	None	No	0	0	0	10-17 cm mixed topsoil over whole right-of-way. Finer texture.
< 10	< 10	HD	< 10	< 10	HD	None	No	0	0	0	20 cm slightly mixed topsoil over trench. Trench better drained.
+154	< 10	< 10	+305	+20	< 10	None	No	-	0	0	No topsoil on trench. Growth more even than controls.
< 10	-15	< 10	< 10	-10	< 10	None	No	0	0	0	Subsoil lower on trench. Topsoil 15 cm.

Table 4.8. Summary of results of differences in soil and vegetation on pipeline rights-of-way in the Black Soil Zone: forage

Site	Soil Type	Texture	Crop	Pipeline Age[1] (Season)	Pipeline Size (mm)	Topsoil Salvaged	Topsoil Mixed[2] Trench Area	Topsoil Mixed[2] Stockpile Area	Topsoil Mixed[2] Working Area	Vegetation Trench Area Live Cover	Vegetation Trench Area Height	Vegetation Trench Area Head
WPb	Orthic Black Chernozem	fine	native fescue	1 (w)	1067.0	all c.o.w.	Y	Y	Y	+10	-67	ND
53	Orthic Black Chernozem	coarse	clover bluegrass	1 (w)	203.2	None	Y	A/B only	N	<10	+58	ND
51	Orthic Black Chernozem	fine	clover bluegrass brome	1 (w)	203.2	None	Y	A/B only	N	-93	-29	ND
79	Eluviated Black Chernozem	fine	alfalfa brome	1 (w)		on trench	Y	A/B only	Y	-73	-13	ND
9b	Orthic Black Chernozem	fine	brome alfalfa	1 (s)	304.8	on trench	Y	Y	Y	<10	-32	ND
58	Calcareous Black Chernozem	fine	mixed grass	2 (w)	508.0	on trench and stockpile	Y	Y	Y	<10	ND	ND
6a	Orthic Humic Luvic Gleysol	fine	native fescue	3 (s)		on trench	N	N	N	+26	+61	ND
48a	Orthic Black Chernozem	fine	native fescue	3 (s)		on trench	Y	Y	Y	-15	-27	ND
4	Orthic Black Chernozem	fine	native fescue	3 (s)	304.8	on trench	N	N	N	<10	+400	ND
7	Regosolic Black Chernozem	fine	alfalfa brome	3 (s)	304.8	on trench	Y	Y	Y	<10	-18	ND
69a	Calcareous Black Chernozem	fine	alfalfa timothy	4 (s)	609.6	on trench	Y	Y	Y	<10	<10	ND
20	Orthic Black Chernozem	coarse	brome	5 (s)	406.4	on trench	Y	Y	N	-10	+336	ND
65	Orthic Black Chernozem	coarse	timothy clover	11 (s)	254.0	on trench and stockpile	N	Y	N	<10	<10	ND

Cropland.

(Percent Difference from Controls[3])

Stockpile Area			Working Area					Change in Topsoil Consistence[4]			
Live Cover	Height	Head	Live Cover	Height	Head	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
+10	-67	ND	-30	-67	ND	None	Yes	N	N	N	Topsoil slightly mixed replaced 9-12 cm deep. Control 13 cm deep. Timothy, creeping red fescue seeded, many native species regenerated.
<10	+16	ND	<10	-17	ND	None	No	N	N	N	Scotch thistle 26-50 percent cover on stockpile area.
-11	+14	ND	<10	<10	ND	None	No	-	N	N	Finer texture on trench. Cattle use trench as path. Dandelions common on trench.
-13	+44	ND	-46	+25	ND	None	No	N	N	-	3 cm C horizon on work area surface. 6 cm mixed topsoil on trench. Green smartweed on trench and working areas.
<10	-27	ND	<10	-27	ND	None	No	N	N	N	Mixed topsoil 10-15 cm over right-of-way. Crested wheatgrass on trench.
<10	ND	ND	<10	ND	ND	None	Yes	N	N	N	Mixed topsoil leveled over whole right-of-way. No evidence of compaction. Vegetation uniform.
-17	+29	ND	-26	+39	ND	None	No	N	N	N	15 cm topsoil over whole right-of-way Clover, timothy, brome seeded. Timothy not compatable with pasture use.
<10	<10	ND	<10	-14	ND	None	No	-	-	N	5-15 cm mixed topsoil over whole right-of-way. Timothy dominant. Rough fescue regeneration on working and stockpile areas.
<10	+211	ND	<10	+344	ND	None	No	N	N	N	14 cm topsoil over 16 cm mixed topsoil on trench. Brome, crested wheatgrass seeded, Canada thistle.
<10	<10	ND	<10	<10	ND	None	Yes	N	N	N	Canada thistle and timothy also on right-of-way. Topsoil mix mostly A horizon. 20 cm on trench.
<10	<10	ND	<10	<10	ND	None	No	N	N	N	Mixed topsoil 12-18 cm. Control 33 cm. Uniform cover timothy/alfalfa.
-42	+109	ND	-42	+54	ND	None	No	N	-	-	Compaction evident on working and stockpile areas. Goldenrod, buckbrush, pasture, sage weeds.
<10	<10	ND	<10	<10	ND	None	No	N	N	N	Topsoil 10 cm over trench. Mixed topsoil 19 cm on stockpile area. No B horizon. Dandelion weeds.

Table 4.8 (Continued)

Site	Soil Type	Texture	Crop	Pipeline Age[1] (Season)	Pipeline Size (mm)	Topsoil Salvaged	Topsoil Mixed[2] Trench Area	Topsoil Mixed[2] Stockpile Area	Topsoil Mixed[2] Working Area	Vegetation Trench Area Live Cover	Vegetation Trench Area Height	Vegetation Trench Area Head
1	Orthic Black Chernozem	fine	clover brome	11 (s)	254.0	on trench	Y	Y	N	+32	+340	MD
6c	Orthic Humic Luvic Gleysol	fine	native fescue	15 (s)		None	Y	Y	N	+26	+39	MD
45b	Orthic Black Chernozem	fine	native fescue	15 (s)		None	Y	Y	Y	<10	-46	MD
48c	Orthic Black Chernozem	fine	native fescue	22 (s)	914.4	None	Y	Y	Y	<10	-18	MD
6b	Orthic Humic Luvic Gleysol	fine	native fescue	22 (s)	914.4	None	Y	Y	Y	+43	+57	MD
WPa	Orthic Black Chernozem	fine	native fescue	22 (s)	914.4	None	Y	Y	Y	-30	+100	MD
9a	Orthic Black Chernozem	fine	brome alfalfa	69 (s)	203.2	on trench	Y	Y	N	<10	-37	MD
69b	Calcareous Black Chernozem	fine	alfalfa timothy		203.2	None	Y	Y	Y	<10	<10	MD
69c	Calcareous Black Chernozem	fine	alfalfa timothy		304.8	None	Y	Y	Y	<10	<10	MD
62	Black Solodized Solonetz	fine	clover bluegrass	2 (w)	508.0	on trench and stockpile	Y	Y	N	<10	+483	MD
72b	Black Solodized Solonetz	fine	alfalfa	5 (s)	304.8	None	Y	Y	Y	+14	<10	MD
56a	Black Solod	fine	clover brome	6 (s)	406.4	on trench	A/B only	Y	N	<10	+21	MD
67	Black Solodized Solonetz	fine	alfalfa brome	11 (s)	254.0	on trench	N	Y	Y	<10	<10	MD
72a	Black Solodized Solonetz	fine	alfalfa	19 (s)	304.8	None	Y	Y	N	-14	+14	MD
56b	Black Solod	fine	clover brome			None	Y	Y	N	-57	+37	MD

1 (w) - winter construction
(s) - summer construction

2 A/B only - only A and B soil horizon mixed
Y - topsoil mixed with subsoil (C horizon) or topsoil absent
N - topsoil not mixed

3 + - percentage higher than controls
- - percentage lower than controls
MD - no data

4 N - no change from control soils
- - firmer consistence than control soils
+ - looser

(Percent Difference from Controls[3])

Stockpile Area			Working Area					Change in Topsoil Consistence[4]			
Live Cover	Height	Weed	Live Cover	Height	Weed	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
-37	+100	MD	<10	+120	MD	15 cm	No	+	+	+	Slightly mixed topsoil 8 cm on trench. Mixed topsoil 6 cm on stockpile area. Trench - Canada thistle, weedy.
<10	<10	MD	<10	+25	MD	None	No	M	M	M	Timothy, clover, dandelions over right-of-way. Canada thistle on trench. Timothy not compatable with pasture use.
<10	-50	MD	<10	-41	MD	None	Yes	-	M	-	No topsoil on trench. 15 cm subsoil on top of stockpile area. Mixed topsoil 8 cm on working area. Timothy, clover, rough fescue, thistle on right-of-way.
<10	-77	MD	<10	-36	MD	10 cm	No	M	M	M	Subsoil/topsoil mix on stockpile and working areas 5-12 cm. No topsoil on trench. Canada thistle, clover timothy.
+52	<10	MD	+17	+74	MD	None	No	M	M	M	5-30 cm subsoil on surface of right-of-way. Topsoil below. Timothy, clover, Canada thistle dominate. 15 cm crown on trench.
-38	-77	MD	-50	+167	MD	None	Yes	-	-	-	Canada thistle dominant on trench and working areas, stinkweed and mustard on stockpile areas. C.F. WPG.
<10	-30	MD	<10	<10	MD	None	Yes	M	M	M	Crested wheatgrass seeded on trench and stockpile areas. 10-15 cm subsoil/topsoil mix on trench and stockpile.
<10	<10	MD	<10	<10	MD	None	No	M	M	M	10-25 cm layer subsoil/topsoil mix on surface of working and stockpile areas. Uniform crop.
<10	<10	MD	<10	<10	MD	None	No	M	M	M	10-25 cm layer subsoil/topsoil mix on surface of working and stockpile areas. Uniform crop.
-17	+280	MD	-17	+380	MD	None	No	M	-	M	10-14 cm subsoil mixture on surface trench and stockpile areas. No crop, all foxtail. Clover on working area.
-21	<10	MD	-67	-24	MD	None	No	M	M	M	C horizon mixed with A over whole right-of-way. Subsoil looser in trench than control.
<10	+10	MD	<10	+16	MD	None	No	M	M	M	C horizon mixed with A on stockpile area. Foxtail barley, weeds. Looser subsoil in trench.
<10	<10	MD	<10	<10	MD	None	No	M	M	M	Subsoil mixed with topsoil 12-14 cm deep on the work and stockpile areas. Looser subsoil in trench.
-67	+24	MD	-51	+19	MD	None	No	-	M	M	Subsoil mixed with topsoil on trench and stockpile areas. Plantain on stockpile area.
-46	+53	MD	<10	+16	MD	45-60 cm	No	-	-	M	Foxtail barley on trench. Topsoil buried by mixed A, B, and C horizons 20 cm deep on stockpile area.

adjacent off right-of-way soils. A layer of C horizon material was found on the surface of parts of several forage crop sites.

Trench settlement of 15 to 30 cm was found at one annually cropped site (site 81) and 15 and 10 cm at two forage crop sites (site 1 and 48c respectively). In all cases, the sites had fine textured soil. Site 81 was constructed in winter while the others were summer constructed.

Surface stoniness increased at 7 of the 45 sites usually over the trench area only.

Effects on Vegetation

At 16 of the 23 annually cropped Chernozemic sites, the live vegetation cover over the trench varied less than 10 percent from adjacent control areas. Three sites had from 13 to 34 percent increase in cover over the trench while the remaining four sites (two wheat, two barley) had from 28 to 71 percent less cover than control sites. Crop height over the trench varied less than 10 percent from adjacent controls at 13 of the 23 annually cropped sites. Seven sites had increased crop height from 11 to 44 percent. Only three sites had decreases in crop heights varying from 12 to 18 percent. Of the 11 annually cropped sites where head length measurements were taken; 10 varied less than 10 percent from controls over the trench; and 1 barley site had a 21 percent increase in head length over controls.

Similar trends were evident in crop cover height and head length over the stockpile and working areas.

At 12 of the 22 Chernozemic forage crop sites, the live vegetation cover over the trench varied less than 10 percent from adjacent control areas. Five sites showed an increase in cover over the trench of 10 to 43 percent from adjacent controls. A higher proportion of these forage crop sites showed great variability in plant height from controls. The main reason for this trend and similar effects on the stockpile and working areas of forage crop sites is the change in species composition on disturbed areas of the right-of-way from the adjacent control areas. Eleven sites had different grass species seeded on disturbed areas than were present on adjacent control areas and eight additional sites had parts or all of the disturbed areas dominated by weedy species such as dandelion, Canada thistle, Green smartweed, goldenrod, buckbrush and pasture sage.

Decreases in percent live cover and/or plant height on annually cropped Chernozemic sites were due to one or more of the following conditions:

- extensive mixing and dilution of topsoil with B and/or C horizon material; and
- increased drainage and/or a heated pipeline (site 68).

No explanation is apparent for vegetation decreases observed over the stockpile and working areas of site 19.

All native fescue pasture sites on Black Chernozemic soils, except site 4, exhibited decreases in plant cover and/or height. These decreases are due to one or more of the following conditions:

- topsoil - C horizon mixing;
- vegetation with grass/legume species uncompatible with native pasture management and use;
- cattle disturbance of right-of-way prior to vegetation reestablishment; and
- lack of follow up weed control while grass is establishing.

Decreases in percent live cover and/or crop height occurred at six of eleven improved forage cropland sites. The causes of the decreases are the same as those outlined for the native pasture sites.

Increases or little change in percent live cover and/or crop height occurred on annually cropped and forage land, with the following characteristics:

- topsoil unmixed over entire right-of-way; and
- topsoil mixed with C horizon but little or no change in consistence or stoniness.

Expanded characteristics of individual sites with vegetation changes in the Black Soil Zone are presented in Appendix B.

4.2.2.2 Black Solonetzic Soils

Effects on Soils

Over the trench, 89 percent of the annually cropped Solonetzic sites had a mixed topsoil-C horizon layer or no topsoil on the surface. Topsoil was replaced over the trench unmixed on the remainder. Similarly, at forage crop sites, 67 percent of the sites had mixed

topsoil-C horizon over the trench; 17 percent were unmixed and 16 percent had topsoil mixed with B horizon soil only. Mixed topsoil-C horizon occurred less frequently over the stockpile and working areas of annually cropped sites and over the working areas of forage sites. However, all forage sites had mixed topsoil-C horizon material over the stockpile area.

Trench settlement occurred at one fine textured, annually cropped site (10 cm) and at one forage crop site (45 to 60 cm). The former site was 2 years old and the pipeline was constructed in winter. A 30 cm mound was found over the trench of one annually cropped site (No. 60). The same site had harder consistence (crusting) and visible salts over the entire surface of the right-of-way. This site is a 2 year old, winter constructed 508 mm diameter gas pipeline on a fine textured Black Solodized Solonetz.

There was no change in surface stoniness at any of the Solonetzic soil sites. The soils over the trenches of all sites were looser at depth and consequently better drained than the control soils. The B horizon structure and consistence on the stockpile and working area were not noticeably different than the controls.

Effects on Vegetation

Four of the nine annually cropped Solonetzic sites had less than 10 percent difference in live crop cover over the trench, three sites had increased cover from 39 to 192 percent and two sites had crop covers 69 and 100 percent less than controls.

Crop heights over the trenches were shorter at five of the nine annually cropped sites (10 to 100 percent less than controls). Only one annually cropped site had increased crop height (18 percent taller than controls).

Similar trends in crop cover and height were observed on the working and stockpile areas of annually cropped sites.

Of the four annually cropped sites where head length was measured over the trench, two were less than 10 percent different from controls and two showed decreases of 12 percent. All four sites showed less than 10 percent difference in head length over the stockpile and working areas.

Three of the six forage crop sites had less than 10 percent difference in live vegetation cover, one had an increase of 14 percent and two had decreases (14 and 57 percent) over the trench. Four of these sites had increased height of vegetation from 14 to 483 percent while two showed less than 10 percent difference over the trench. As with the Black Chernozems a major cause of the variability in response in vegetation cover and height is the presence of weedy species. Those species observed at the forage crop sites on Black Solonetzic soils included foxtail barley and plantain. The presence of these species may in part be due to the mixture of C horizon material with topsoil.

While the trends in vegetation height were similar on the trench, stockpile and working areas at each site, the differences in cover were more variable. Live cover was lower (17 to 67 percent) over the stockpile areas at four of the six sites compared to the lower values over the trenches at two sites. The effect over the working

areas was intermediate with decreases in cover from 17 to 67 percent at three sites.

Decreases in percent live cover and/or crop height on annually seeded, Black Solonetzic soils appear to be the result of one or more of the following conditions:

- leaving saline/sodic soil parent material on the surface;
- mixing topsoil with saline/sodic parent material; and
- lack of follow up for leveling of mound over trench and weed control.

The reasons for decreases observed at sites 55a and 55b were not readily apparent although increased competition from weeds could be a cause.

Decreases in percent live cover and/or crop height on forage cropland, Black Solonetzic sites appear to be the result of the following conditions:

- topsoil - C horizon mixing; and
- increase in weedy species (foxtail barley and plantain).

Increases or little change in percent liver cover and/or crop height occurred on Black Solonetzic sites with the following general conditions:

- topsoil unmixed; and
- topsoil mixed with B and/or C horizon material but no change in consistence or stoniness.

Expanded characteristics of Black Solonetzic soils experiencing changes in vegetation are presented in Appendix B.

4.2.3 Dark Brown Soil Zone

A total of 22 sites were examined in the Dark Brown Soil Zone (Table 4.9). Of the 22 sites, 18 were on Dark Brown Chernozemic soils and 4 on Dark Brown Solodized Solonetzic soils. Nine sites were under annual cropping (one irrigated) and 13 were under native or improved forage crops. The pipelines ranged from 3 to 23 years old and from 76.2 mm to 863.6 mm in diameter.

4.2.3.1 Dark Brown Chernozemic Soils

Effects on Soil

Topsoil was found to be absent or thoroughly mixed with C horizon material over the trench at all Chernozemic sites. Of these, soil was not salvaged at eight forages sites and four annually cropped sites. Similarly, only one site had unmixed topsoil over the stockpile area. Over the working area, 12 of the 18 sites had unmixed topsoil on the surface.

The depth of mixed or unmixed topsoil over the rights-of-way varied from 5 to 30 cm, compared to 10 to 20 cm for adjacent control soils.

Trench settlement of 5 to 30 cm was evident at 22 percent of the sites; a 3 year old annually cropped site; and at three, 5 year old

Table 4.9 Summary of results of differences in soil and vegetation on pipeline rights-of-way in the Dark Brown Soil Zone.

Site	Soil Type	Texture	Crop	Pipeline Age[1] (Season)	Pipeline Size (mm)	Topsoil Salvaged	Topsoil Mixed[2] Trench Area	Topsoil Mixed[2] Stockpile Area	Topsoil Mixed[2] Working Area	Vegetation Trench Area Live Cover	Vegetation Trench Area Height	Vegetation Trench Area Head
45	Orthic Dark Brown Chernozem	fine	wheat	3 (s)	76.2	on trench	Y	Y	Y	-51	-20	<10
13	Orthic Dark Brown Chernozem	fine	canola	5 (s)	101.6	on trench	Y	Y	Y	<10	<10	ND
15	Orthic Dark Brown Chernozem	fine	wheat	5 (s)	101.6	on trench	Y	N	N	-64	-31	ND
17	Orthic Dark Brown Chernozem	fine	barley	5 (s)	406.4	None	Y	Y	N	-40	<10	ND
21	Orthic Dark Brown Chernozem	coarse	barley	5 (s)	406.4	None	Y	Y	N	<10	+16	-15
42	Orthic Dark Brown Chernozem	coarse	wheat	5	203.2	on trench	Y	Y	N	-86	-30	<10
39	Calcareous Dark Brown Chernozem	fine	irrig. durum	5	203.2	None	Y	Y	Y	-77	-13	<10
11	Orthic Dark Brown Chernozem	fine	wheat	6 (w)	203.2	all r.o.w.	Y	Y	Y	<10	<10	ND
43	Orthic Dark Brown Chernozem	fine	durum	6 (s)	152.4	None	Y	Y	N	<10	<10	<10
47	Orthic Dark Brown Chernozem	fine	native mixed grass	3 (s)	76.2	None	Y	Y	N	-51	+100	ND
46	Regosolic Dark Brown Chernozem	fine	alfalfa brome	3 (s)	76.2	None	Y	Y	N	-38	<10	ND

(Percent Difference from Controls[3])

Stockpile Area			Working Area					Change in Topsoil Consistence[4]			
Live Cover	Height	Head	Live Cover	Height	Head	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
<10	<10	<10	-44	<10	<10	5-10 cm	No	N	N	N	Trench loosely packed - cracking in soil on trench. B horizon working area harder than control. Mixed topsoil 10-20 cm.
<10	<10	ND	<10	<10	ND	None	No	N	N	N	Mixed topsoil 5 cm deep on trench. 20 cm on rest of right-of-way. Control topsoil 20 cm. Uniform crop.
-47	-23	ND	-52	-11	ND	None	No	+	+	+	Mixed topsoil, 30 cm deep on trench. Soil looser, drier on right-of-way. More wild rose on stockpile area.
<10	<10	ND	+32	<10	ND	None	No	+	+	N	Topsoil mixed and looser on trench and stockpile areas.
+11	+11	-23	+11	+11	<10	None	No	N	N	N	Topsoil mixed, 15 cm deep on trench and stockpile areas. Canada thistle over trench.
-48	<10	<10	+200	+15	<10	None	No	-	-	-	Topsoil slightly less friable on right-of-way. Subsoil on trench hard and dry. More buckbrush on working area.
-77	<10	<10	-77	<10	<10	None	No	N	N	N	Sprinkler irrigation. Original surface covered with 20-30 cm mixed topsoil. Compaction below plough layer, drier on right-of-way. Trench settled and rebackfilled by farmer.
-12	<10	ND	<10	<10	ND	None	No	+	+	N	Mixed topsoil 15-25 cm deep over right-of-way. Looser on stockpile and trench areas. More stinkweed and Canada thistle on trench. Stones picked.
<10	+17	<10	<10	<10	-14	None	Yes	N	N	N	Stones on trench and stockpile areas. Mixed topsoil 5-12 cm deep. Hard subsoil at 12 cm on trench. Canada thistle on trench.
-22	+120	ND	+100	+100	ND	None	No	N	N	N	No topsoil on trench or stockpile areas. 5 cm on work area 10 cm on control. Crested wheatgrass on trench.
-30	<10	ND	-53	-33	ND	None	No	N	N	N	C horizon at 10 cm on trench and working areas compacted. Gopher holes on trench. More weeds on trench and stockpile areas.

Table 4.9 (Continued)

Site	Soil Type	Texture	Crop	Pipeline Age[1] (Season)	Pipeline Size (mm)	Topsoil Salvaged	Topsoil Mixed[2] Trench Area	Topsoil Mixed[2] Stockpile Area	Topsoil Mixed[2] Working Area	Vegetation Trench Area Live Cover	Vegetation Trench Area Height	Vegetation Trench Area Head
40	Calcareous Dark Brown Chernozem	fine	grass-legume	5	203.2	None	Y	Y	N	-15	-38	ND
14	Orthic Dark Brown Chernozem	fine	native mixed grass	5 (s)	101.6	None	Y	Y	Y	<10	-27	ND
41	Regosolic Dark Brown Chernozem	coarse	crested wheatgrass alfalfa	5	203.2	None	Y	Y	N	+71	ND	ND
16	Orthic Dark Brown Chernozem	fine	native mixed grass	5 (s)	406.4	None	Y	Y	N	<10	+36	ND
12	Orthic Dark Brown Chernozem	fine	native mixed grass	6 (w)	203.2	None	Y	Y	N	<10	+143	ND
10	Orthic Dark Brown Chernozem	fine	clover brome	6 (s)	203.2	None	Y	Y	N	+23	ND	ND
44	Orthic Dark Brown Chernozem	coarse	grass-legume	6 (s)	152.4	on trench	Y	Y	Y	-76	<10	ND
28d	Dark Brown Solodized Solonetz	fine	R.W. rye crested wheatgrass	10 (s)	1067.0	None	Y	Y	Y	<10	<10	ND
28c	Dark Brown Solodized Solonetz	fine	R.W. rye crested wheatgrass	13 (s)	914.8	on trench	Y	Y	N	+28	+131	ND
28b	Dark Brown Solodized Solonetz	fine	R.W. rye crested wheatgrass	17 (s)	863.6	on trench	Y	Y	N	+125	+131	ND
28a	Dark Brown Solodized Solonetz	fine	R.W. rye crested wheatgrass	22 (s)	863.6	on trench	Y	Y	Y	+11	<10	ND

1
(w) - winter construction
(s) - summer construction

2
A/B only - only A and B soil horizon mixed
Y - topsoil mixed with subsoil (C horizon) or topsoil absent
N - topsoil not mixed

3
+ - percentage higher than controls
- - percentage lower than controls
ND - no data

4
N - no change from control soils
- - firmer consistence than control soils
+ - looser

(Percent Difference from Controls[3])

Stockpile Area			Working Area					Change in Topsoil Consistence[4]			
Live Cover	Height	Head	Live Cover	Height	Head	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
-17	-13	ND	<10	<10	ND	30 cm	No	-	N	N	30 cm subsoil/topsoil mix on stockpile area. Canada thistle dominant. Legumes poorest on stockpile area.
+10	+23	ND	+62	+93	ND	None	Yes	N	N	N	No topsoil on trench and work areas. Mixed profile on stockpile area. Seeded to alfalfa/brome. Weedy, patchy.
<10	ND	ND	+87	ND	ND	15 cm	Yes	N	N	N	5 cm subsoil on surface of stockpile area. No topsoil on trench. Foxtail and wild rose on trench and working area.
-11	<10	ND	<10	+45	ND	10 cm	Yes	N	-	N	Foxtail barley and Canada thistle on trench. 10 cm firm subsoil on surface of stockpile area.
-44	+28	ND	+102	+28	ND	None	Yes	N	N	N	Buckbrush on trench. Crested wheatgrass seeded on right-of-way. Stockpile area has 5 cm loose, dry subsoil on surface.
+23	ND	ND	+23	ND	ND	None	Yes	N	N	N	15 cm mound mixed topsoil on trench. Increase weeds on right-of-way. Canada thistle on trench. Alfalfa and crested wheatgrass on trench.
+28	+39	ND	-15	<10	ND	None	No	N	N	N	15-20 cm subsoil/topsoil mix on surface of trench and stockpile areas. Mixed topsoil 10 cm deep on working area. Dandelion and foxtail on trench.
+21	<10	ND	+61	<10	ND	None	No	-	N	N	20 cm mound on trench. 5 cm subsoil on surface of working and stockpile areas. No topsoil on trench. Very weedy. Foxtail barley, sage, gumweed.
+61	<10	ND	+71	+200	ND	None	No	N	N	N	Mixed topsoil 25 cm on trench. Crested wheatgrass and alfalfa seeded on right-of-way.
+43	-31	ND	+71	+200	ND	None	No	N	N	N	Mixed topsoil 5-25 cm deep on trench and stockpile areas. Canada thistle, goldenrod and other weeds on trench. Crested wheatgrass and alfalfa seeded.
+36	-31	ND	+43	-31	ND	None	Yes	-	N	N	Mixed topsoil 5-25 cm deep over right-of-way. Stonier on stockpile area. Firmer on trench.

forage sites. While settlment was not evident at the 5 year old irrigated site (39), information from the landowner suggests that the trench had settled and had been further backfilled by the landowner.

Stoniness increased over the trench at 33 percent of the sites. These sites were all ones where topsoil had not been salvaged. Topsoil consistence was generally unchanged at most sites. However, one annually cropped site (42) had slightly less topsoil friability over the right-of-way and the subsoil in the trench was hard and dry. Less friable subsoil material (C horizon) was also found over the trench at site 40 and over the stockpile area of site 16. Looser, fine textured topsoil was found over the trench and stockpile areas of three annually cropped sites.

Effects on Vegetation

Three of the nine annually cropped sites had less than 10 percent difference in live vegetation cover and crop height over the trench. Five sites had decreases in cover from 12 to 77 percent over the trench and decreases in height from less than 10 to 31 percent. The 77 percent decrease in cover occurred at the irrigated Durum site. The remaining annually cropped site (21) had less than 10 percent difference in cover and a 16 percent increase in plant height. However, this site was the only one of the nine to show a decrease in head length (15 percent) over the trench. The anomalous results may be the result of the presence of Canada thistle which inflated the cover and height estimates. Head lengths measured at four other sites showed less than 10 percent difference from controls.

(Percent Difference from Controls[3])

Stockpile Area			Working Area					Change in Topsoil Consistence[4]			
Live Cover	Height	Head	Live Cover	Height	Head	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
-17	-13	ND	<10	<10	ND	30 cm	No	-	N	N	30 cm subsoil/topsoil mix on stockpile area. Canada thistle dominant. Legumes poorest on stockpile area.
+18	+23	ND	+62	+93	ND	None	Yes	N	N	N	No topsoil on trench and work areas. Mixed profile on stockpile area. Seeded to alfalfa/brome. Weedy, patchy.
<10	ND	ND	+87	ND	ND	15 cm	Yes	N	N	N	5 cm subsoil on surface of stockpile area. No topsoil on trench. Foxtail and wild rose on trench and working area.
-11	<10	ND	<10	+45	ND	10 cm	Yes	N	-	N	Foxtail barley and Canada thistle on trench. 10 cm firm subsoil on surface of stockpile area.
-44	+28	ND	+102	+28	ND	None	Yes	N	N	N	Buckbrush on trench. Crested wheatgrass seeded on right-of-way. Stockpile area has 5 cm loose, dry subsoil on surface.
+23	ND	ND	+23	ND	ND	None	Yes	N	N	N	15 cm mound mixed topsoil on trench. Increase weeds on right-of-way. Canada thistle on trench. Alfalfa and crested wheatgrass on trench.
+28	+39	ND	-15	<10	ND	None	No	N	N	N	15-20 cm subsoil/topsoil mix on surface of trench and stockpile areas. Mixed topsoil 10 cm deep on working area. Dandelion and foxtail on trench.
+21	<10	ND	+61	<10	ND	None	No	-	N	N	20 cm mound on trench. 5 cm subsoil on surface of working and stockpile areas. No topsoil on trench. Very weedy. Foxtail barley, sage, gumweed.
+61	<10	ND	+71	+200	ND	None	No	N	N	N	Mixed topsoil 25 cm on trench. Crested wheatgrass and alfalfa seeded on right-of-way.
+43	-31	ND	+71	+200	ND	None	No	N	N	N	Mixed topsoil 5-25 cm deep on trench and stockpile areas. Canada thistle, goldenrod and other weeds on trench. Crested wheatgrass and alfalfa seeded.
+36	-31	ND	+43	-31	ND	None	Yes	-	N	N	Mixed topsoil 5-25 cm deep over right-of-way. Stonier on stockpile area. Firmer on trench.

forage sites. While settlment was not evident at the 5 year old irrigated site (39), information from the landowner suggests that the trench had settled and had been further backfilled by the landowner.

Stoniness increased over the trench at 33 percent of the sites. These sites were all ones where topsoil had not been salvaged. Topsoil consistence was generally unchanged at most sites. However, one annually cropped site (42) had slightly less topsoil friability over the right-of-way and the subsoil in the trench was hard and dry. Less friable subsoil material (C horizon) was also found over the trench at site 40 and over the stockpile area of site 16. Looser, fine textured topsoil was found over the trench and stockpile areas of three annually cropped sites.

Effects on Vegetation

Three of the nine annually cropped sites had less than 10 percent difference in live vegetation cover and crop height over the trench. Five sites had decreases in cover from 12 to 77 percent over the trench and decreases in height from less than 10 to 31 percent. The 77 percent decrease in cover occurred at the irrigated Durum site. The remaining annually cropped site (21) had less than 10 percent difference in cover and a 16 percent increase in plant height. However, this site was the only one of the nine to show a decrease in head length (15 percent) over the trench. The anomalous results may be the result of the presence of Canada thistle which inflated the cover and height estimates. Head lengths measured at four other sites showed less than 10 percent difference from controls.

A similar trend was evident over the stockpile areas except where decreases in cover and height on the trench appear to be caused by loosely packed backfill. This results in drier, cracked soil over the trench (site 45). In this case, the same decreases in cover and height were not found on the stockpile area.

The trends on the working areas at the nine annually cultivated sites do not follow those on the trench and stockpile areas. Three sites showed less than 10 percent difference in crop cover and height, but three other sites showed increases in cover from 11 to 200 percent. In these cases, C horizon had not been mixed with topsoil over the working areas. Except for the site with the 200 percent increase in cover, no changes in soil consistence were noted. Site 42, with a 200 percent increase in cover over the working area had less friable soil and an increased cover of buckbrush.

The working areas of the remaining three sites had decreases in cover ranging 98 to 77 percent corresponding to the severest decreases over the trenches.

The largest decrease in crop cover was noted on the trench, stockpile and working areas of site 39, sprinkle irrigated Durum wheat on a Calcareous Dark Brown Chernozem.

At five of the nine native and improved forage crop sites decreased cover and/or height was evident over the trench. These sites had no topsoil at the trench surface or thoroughly mixed topsoil and C horizon material. In most cases, these sites also had increased cover of weedy species including Canada thistle, dandelion and foxtail barley.

The other four sites had increases of vegetation cover and/or height over the trench. Three of these sites had a thin, 5 to 10 cm, layer of C horizon material on the surface over mixed topsoil and C horizon material. The fourth site had a 15 to 20 cm layer of mixed topsoil-C horizon material over the trench. The increased cover and/or height can be attributed to the increase in weedy species over the trenches at these sites. Species noted include foxtail barley, wild rose, Canada thistle and buckbrush.

Similar trends are apparent over the stockpile areas of all nine forage crop sites. Topsoil was either lost in the backfill or buried under a thin layer of C horizon or topsoil-C horizon mixture.

Over the working areas, two sites had decreased vegetation cover and height. One of these, a fine textured Rego Dark Brown Chernozem (site 46), had a compacted C horizon at 10 cm, although the topsoil remained unchanged from the control. The other site (44) had 10 cm of mixed C horizon over the surface.

The working areas of the other seven forage crop sites had increased, or less than 10 percent difference in cover and height compared to adjacent controls. In six of these seven sites, the topsoil was not mixed over the working areas. Topsoil had been removed entirely on the other site (site 14). No changes in topsoil consistence were noted over the working areas. Increases in cover of weedy species and/or seeded species different from adjacent control areas were evident at all seven sites.

Decreases in crop cover and/or height on annually cropped Dark Brown Chernozemic sites appear to be the result of one or more of the following general conditions:

- shallow depth of replaced topsoil;
- looseness of topsoil; and
- compacted subsoil in working area.

At site 15, the reasons for reduced cover were not readily apparent although the looser, drier topsoil may be one factor. Causes of reduced cover were also not apparent at sites 21 and 42. Suspected causes could possibly be the immobilization of macronutrients in the coarse textured soils by the lime mixed into the topsoil. This could be compounded by competition from weeds, particularly over the trench areas.

Decreases in percent live cover and crop height on the irrigated Durum wheat crop on Calcareous Dark Brown Chernozems appear to the the result of:

- compacted subsoil layer and drier soils over the right-of-way; and
- possibly compounded by additional lime in the mixed topsoil - C horizon material which may immobilize nutrients.

Decreases in percent live cover and/or crop height in forage cropland on Dark Brown Chernozems appear to be the result of one or more of the following conditions:

- absence of topsoil or thorough mixing with calcareous C horizon material;

- compaction over trench and working areas (site 46); and
- gopher activity over trench.

Expanded characteristics of sites showing vegetation decreases are presented in Appendix C.

4.2.3.2 Dark Brown Solonetzic Soils

Effects of Soil

Topsoil was found to be thoroughly mixed over the trench on three of the four fine textured, Dark Brown Solodized Solonetz sites. A 20 cm mound of C horizon material was found over the trench of the fourth site (site 28d). Similarly mixed topsoil-C horizon material was found 4 to 25 cm deep over the stockpile areas at three sites and a 5 cm layer of C horizon material was found on the stockpile area surface of the fourth site. The topsoil over two of the working areas was unaffected, while one had a mixed topsoil-C horizon surface layer, and one had a 5 cm layer of C horizon spread over the working area surface.

No trench settlement was evident at the Solonetzic soil sites. Stoniness increased over the stockpile area of site 28a only. Firmer consistence was evident in the surface material over the trenches at sites 28d (mounded - no topsoil) and 28a.

Effects on Vegetation

All four sites were under Russian wild rye/crested wheatgrass forage cover. Total live vegetation cover increased at all sites over the entire right-of-way except the mounded trench with no topsoil at

site 28d. Cover changed less than 10 percent relative to controls in this area. Vegetation height decreased over the stockpile areas at two sites and the working area of one site. Increases in height were observed at sites 28b and 28c over the trench and working areas. At all but the oldest site (28a), alfalfa was seeded with the crested wheatgrass. A variety of weedy species were prevalent at all sites. Gumweed and foxtail barley dominated the youngest (7 year old) site (28d). Sage and junegrass were common on the 12 and 23 year old rights-of-way while Canada thistle, goldenrod and yarrow were dominant over the trench of the 17 year old site.

Total vegetation cover and height vary radically. They are affected by prevalent weedy species. The presence of the weedy species coincides with the absence or dilution of topsoil and lime on the surface. Weed control management may have alleviated this effect and fertilization could have improved the reestablishment of grass species.

4.2.4 Brown Soil Zone

A total of 48 sites were examined in the Brown Soil Zone (Table 4.10). Of these, 24 were on Brown Chernozemic soils and 24 were on Brown Solonetzic Soils.

There were 16 sites under annual cropping (three irrigated) and 32 under native or improved forage crops. Three of the improved forage crop sites were also irrigated. The pipelines ranged from 2 to 24 years old and from 254 mm to 1067 mm in diameter.

Table 4.10 Summary of results of differences in soils and vegetation on pipeline rights-of-way in the Brown Soil Zone.

Site	Soil Type	Texture	Crop	Pipeline			Topsoil Mixed[2]			Vegetation		
				Age[1] (Season)	Size (mm)	Topsoil Salvaged	Trench Area	Stockpile Area	Working Area	Trench Area		
										Live Cover	Height	Head
32d	Orthic Brown Chernozem	coarse	fall rye	7 (s)	1067.0	None	Y	Y	Y	-48	<10	-10
22c	Orthic Brown Chernozem	fine	irrig. barley	13 (s)	914.4	on trench	Y	Y	Y	<10	-14	<10
32c	Orthic Brown Chernozem	coarse	fall rye	12 (s)	914.4	None	Y	Y	Y	-48	+10	-10
32b	Orthic Brown Chernozem	coarse	fall rye	17 (s)	863.6	None	Y	Y	Y	-48	<10	-18
22b	Orthic Brown Chernozem	fine	irrig. barley	17 (s)	863.6	on trench	Y	Y	Y	<10	-14	-10
22a	Orthic Brown Chernozem	fine	irrig. barley	24 (s)	863.6	on trench	Y	Y	Y	<10	-15	<10
32a	Orthic Brown Chernozem	coarse	fall rye	23 (s)	863.6	None	Y	Y	Y	-38	-14	-16
34d	Orthic Brown Chernozem	coarse	native pasture	7 (s)	1067.0	None	Y	Y	Y	-79	-26	ND
33d	Orthic Brown Chernozem	coarse	created wheatgrass alfalfa	11 (s)	1067.0	None	Y	Y	Y	-74	ND	ND
24c	Calcareous Brown Chernozem	coarse	irrig. clover bluegrass	13 (s)	914.4	on trench	N	N	N	<10	ND	ND
33c	Orthic Brown Chernozem	coarse	created wheatgrass alfalfa	13 (s)	914.4	None	Y	Y	Y	-58	ND	ND

(Percent Difference from Controls[3])								Change in Topsoil Consistence[4]			
Stockpile Area			Working Area								
Live Cover	Height	Head	Live Cover	Height	Head	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
-48	-20	-15	-48	<10	<10	None	No	-	-	-	Mixed topsoil 5-20 cm deep on right-of-way. Slightly firmer. Russian thistle as control. Carbonates at surface.
<10	-19	<10	<10	-19	<10	None	No	M	M	M	Flood irrigation. Mixed topsoil 10-20 cm on right-of-way. Trench settling has been disruptive. Subsoil compacted whole right-of-way. Wild oats first 2 to 3 years.
-48	-11	<10	-48	-20	-15	None	No	-	-	-	Topsoil/subsoil mix 10-15 cm deep on right-of-way. Slightly firmer. Carbonates on surface.
-48	-18	-20	-48	-11	<10	None	No	-	-	-	Finer textured subsoil/topsoil mix 20-25 cm deep on trench and stockpile areas. Slightly firmer. Carbonates on trench.
10	-16	<10	<10	-16	<10	None	No	M	M	M	Flood irrigation. Mixed topsoil 15-20 cm on right-of-way. Trench settling has been disruptive. Subsoil compacted. Brome grass.
<10	-13	<10	<10	-12	<10	None	No	M	M	M	Flood irrigation. Mixed topsoil 15-20 cm on right-of-way. Trench settling has been diruptive. Subsoil compacted.
-48	-11	-11	-48	-18	-20	None	No	M	M	-	Mixed topsoil 5-25 cm deep on right-of-way. Carbonates at surface. Working area slightly firmer.
-51	-26	ND	-57	<10	ND	None	No	-	-	M	Subsoil 5-10 cm deep on working and stockpile area. No topsoil on trench. 15 cm mound on trench. Crested wheatgrass seeded.
-74	ND	ND	-84	ND	ND	None	No	-	-	-	Mixed topsoil 10-20 cm deep on right-of-way. Yellow gallardia weeds. Carbonates on surface.
<10	ND	ND	- 10	ND	ND	None	No	M	-	M	Very hard topsoil on stockpile area. Topsoil 10-20 cm deep. Heated line poor growth on dry year.
-69	ND	ND	-74	ND	ND	None	No	-	-	-	Mixed topsoil 10-15 cm deep on right-of-way. Slightly firmer. Yellow gallardia weeds.

Table 4.10 (Continued)

Site	Soil Type	Texture	Crop	Pipeline			Topsoil Mixed[2]			Vegetation Trench Area		
				Age[1] (Season)	Size (mm)	Topsoil Salvaged	Trench Area	Stockpile Area	Working Area	Live Cover	Height	Head
25c	Orthic Brown Chernozem	coarse	native pasture	13 (s)	914.4	None	Y	Y	N	+14	-55	ND
34c	Orthic Brown Chernozem	coarse	native pasture	12 (s)	914.4	None	Y	Y	N	-56	-17	ND
23c	Orthic Regosol	coarse	native pasture	13 (s)	914.4	None	N	N	N	+33	<10	ND
23b	Orthic Regosol	coarse	native pasture	17 (s)	863.6	None	N	N	N	+71	+30	ND
34b	Orthic Brown Chernozem	coarse	native pasture	17 (s)	863.6	None	Y	Y	N	-91	-48	ND
25b	Orthic Brown Chernozem	coarse	native pasture	17 (s)	863.6	None	Y	Y	Y	+47	-18	ND
33b	Orthic Brown Chernozem	coarse	crested wheatgrass alfalfa	19 (s)	863.6	None	Y	Y	Y	+10	ND	ND
24b	Calcareous Brown Chernozem	coarse	irrig. clover bluegrass	17 (s)	863.6	on trench	N	N	N	<10	ND	ND
24a	Calcareous Brown Chernozem	coarse	irrig. clover bluegrass	24 (s)	863.6	on trench	Y	Y	N	<10	ND	ND
33a	Orthic Brown Chernozem	coarse	crested wheatgrass alfalfa	24 (s)	863.6	None	Y	Y	Y	-58	ND	ND
25a	Orthic Brown Chernozem	coarse	native pasture	24 (s)	863.6	None	Y	Y	N	-57	-68	ND
34a	Orthic Brown Chernozem	coarse	native pasture	23 (s)	863.6	None	Y	Y	Y	-83	-52	ND
23a	Orthic Regosol	coarse	native pasture	24 (s)	863.6	None	N	N	N	+14	-25	ND

(Percent Difference from Controls[3])											
Stockpile Area			Working Area					Change in Topsoil Consistence[4]			
Live Cover	Height	Head	Live Cover	Height	Head	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
<10	-14	ND	+33	-23	ND	None	Yes	N	-	-	25 cm mound on trench. Surface of trench and stockpile areas hard. Foxtail barley, gumweed and sage weeds on trench.
-57	<10	ND	-76	<10	ND	None	No	N	N	N	No topsoil on trench. 5 cm subsoil on stockpile area. 15 cm mound on trench. Crested wheatgrass seeded, sage weeds.
<10	+15	ND	+33	-40	ND	None	No	N	N	N	Sand dune area 30 cm mound on trench. Sage, blueburr weeds dominant.
+33	<10	ND	+33	-40	ND	None	No	N	N	N	Sand dune area 30 cm mound on trench. Wolf willow, rose, sage weeds dominant.
-67	-26	ND	-76	<10	ND	None	No	N	N	N	30 cm mound on trench. Ck horizon on trench and stockpile areas. Sage weeds.
<10	<10	ND	<10	-14	ND	None	No	-	N	N	25 cm mound. Hard dry subsoil on trench. Topsoil mixed on stockpile and working areas. Gumweed, sage weeds.
-74	ND	ND	-69	ND	ND	None	No	-	-	N	Finer texture on trench, working area and stockpile in mixed topsoil. 20-25 cm deep. Sage and gallardia on working area.
<10	ND	ND	<10	ND	ND	None	No	N	N	N	Slightly hard below 15 cm on trench and stockpile. Mound impeded irrigation. Grazed pasture.
<10	ND	ND	<10	ND	ND	None	No	-	-	N	Finer texture on trench and stockpile in mixed topsoil. Mound impeded irrigation. Grazed pasture.
-47	ND	ND	-74	ND	ND	None	No	N	N	N	Topsoil mixed on right-of-way. No weeds.
<10	<10	ND	+52	-27	ND	None	Yes	-	N	N	No topsoil on trench. Loam subsoil hard, dry many gopher/badger holes. Sage, gumweed weeds.
-70	-35	ND	-67	-24	ND	None	No	N	N	N	45 cm mound on trench. Ck over all right-of-way. 5-10 cm deep. Sage weeds.
+57	-15	ND	+33	<10	ND	None	No	N	N	N	30 cm mound on trench. Sand dune area. Sage, rose, licorice weeds. Crested wheatgrass seeded.

Table 4.10 (Continued)

Site	Soil Type	Texture	Crop	Pipeline Age[1] (Season)	Pipeline Size (mm)	Topsoil Salvaged	Topsoil Mixed[2] Trench Area	Topsoil Mixed[2] Stockpile Area	Topsoil Mixed[2] Working Area	Vegetation Trench Area Live Cover	Vegetation Trench Area Height	Vegetation Trench Area Head
38d	Brown Solodized Solonetz	fine	wheat	10 (s)	1067.0	on trench	Y	Y	N	ND	+15	<10
38c	Brown Solodized Solonetz	fine	wheat	13 (s)	914.4	on trench	Y	Y	Y	ND	-13	<10
26c	Brown Solodized Solonetz	fine	barley	13 (s)	914.4	on trench	Y	Y	N	+52	+25	<10
26b	Brown Solodized Solonetz	fine	barley	17 (s)	863.6	on trench	Y	Y	Y	+43	+22	<10
38b	Brown Solodized Solonetz	fine	wheat	17 (s)	863.6	on trench	Y	Y	Y	ND	<10	<10
31a	Brown Solodized Solonetz	fine	wheat	21 (s)	609.6	all r.o.w.	N	N	N	<10	<10	<10
38a	Brown Solodized Solonetz	fine	wheat	22 (s)	863.6	on trench	Y	Y	Y	ND	<10	<10
26a	Brown Solodized Solonetz	fine	barley	24 (s)	863.6	on trench	Y	Y	N	+52	<10	<10
31b	Brown Solodized Solonetz	fine	wheat	5 (s)		all r.o.w.	N	N	N	<10	<10	<10
35a	Brown Solodized Solonetz	fine	native pasture	6 (s)	254.0	None	Y	Y	Y	-86	+443	ND
36a	Brown Solonetz	fine	native pasture	6 (s)	254.0	None	Y	Y	Y	-89	+200	ND
37d	Brown Solod	fine	native pasture	10 (s)	1067.0	None	Y	Y	Y	-57	+140	ND
37c	Brown Solod	fine	native pasture	13 (s)	914.4	None	Y	Y	Y	-62	+120	ND
27c	Brown Solonetz	fine	native pasture	13 (s)	914.4	None	Y	Y	Y	+24	+128	ND

(Percent Difference from Controls[3])								Change in Topsoil Consistence[4]			
Stockpile Area			Working Area								
Live Cover	Height	Head	Live Cover	Height	Head	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
ND	-37	-11	ND	-25	<10	None	No	N	N	N	Trench subsoil looser than control. Topsoil mixed with Csk on stockpile and trench area. 10-15 cm deep.
ND	-37	<10	ND	-37	-11	None	No	N	N	N	Trench subsoil looser than control. topsoil mixed with Csk on all right-of-way. 15-20 cm deep.
+52	+17	<10	+52	+28	<10	None	No	N	N	N	Finer texture on trench. Topsoil mixed with Csk on trench and stockpile.
+52	+17	<10	<10	-11	<10	None	No	N	N	N	Finer texture on trench. Topsoil mixed with Csk on all right-of-way.
ND	-37	<10	ND	-24	<10	None	No	N	N	N	Finer texture on trench. Topsoil mixed with Csk on all right-of-way, 15 cm deep.
<10	<10	<10	<10	<10	<10	None	No	N	N	N	Right-of-way vegetation same as rest of field.
ND	-24	<10	ND	ND	ND	None	No	N	N	N	Finer texture on trench. topsoil mixed with Csk on all right-of-way.
<10	-11	<10	+52	<10	<10	None	No	N	N	N	Topsoil mixed with Csk on trench and stockpile areas. Looser subsoil in trench.
<10	<10	<10	<10	<10	<10	None	No	N	N	N	Right-of-way vegetation same as rest of field.
-92	+471	ND	-54	+143	ND	None	No	N	N	N	Crested wheatgrass seeded. Foxtail barley, sage weeds. Height difference due to species. 2 to 3 cm layer of subsoil over working and stockpile areas.
-65	+80	ND	-89	+200	ND	None	No	N	N	N	Finer texture on right-of-way. Csk on surface of trench and stockpile areas. Topsoil removed on working area. Very weedy.
-55	+180	ND	-40	+200	ND	None	No	N	N	N	10-30 cm layer Csk on surface all right-of-way. Very weedy.
-40	+200	ND	-34	+220	ND	None	No	N	N	N	20-25 cm mound subsoil on trench. 10-45 cm Csk on working and stockpile areas. Very weedy.
29	+28	ND	+114	+171	ND	None	Yes	-	-	-	10-25 cm Csk on surface of right-of-way. Crested wheatgrass seeded, Foxtail barley, gumweed, sage weeds.

Table 4.10 (Continued)

Site	Soil Type	Texture	Crop	Pipeline Age[1] (Season)	Pipeline Size (mm)	Topsoil Salvaged	Topsoil Mixed[2] Trench Area	Topsoil Mixed[2] Stockpile Area	Topsoil Mixed[2] Working Area	Vegetation Trench Area Live Cover	Vegetation Trench Area Height	Vegetation Trench Area Head
27b	Brown Solonetz	fine	native pasture	17 (s)	863.6	None	Y	Y	Y	-28	+86	ND
37b	Brown Solod	fine	native pasture	17 (s)	863.6	None	Y	Y	Y	-43	+180	ND
29a	Brown Solodized Solonetz	fine	native pasture	21 (s)	609.6	None	Y	Y	Y	<10	+80	ND
30a	Brown Solodized Solonetz	fine	native pasture	21 (s)	609.6	None	Y	Y	N	-93	+220	ND
27a	Brown Solonetz	fine	native pasture	24 (s)	864.6	None	Y	Y	Y	-29	+86	ND
37a	Brown Solod	fine	native pasture	22 (s)	863.6	None	Y	Y	Y	-65	+140	ND
35b	Brown Solodized Solonetz	fine	native pasture	2 (s)	406.0	None	Y	Y	N	-72	+100	ND
30b	Brown Solodized Solonetz	fine	native pasture	5 (s)		None	Y	Y	N	-87	+140	ND
36b	Brown Solonetz	fine	native pasture	2 (s)	406.0	None	Y	Y	Y	-56	<10	ND
29b	Brown Solodized Solonetz	fine	native pasture	5 (s)		None	Y	Y	Y	-75	+140	ND

1
(w) - winter construction
(s) - summer construction

2
A/B only - only A and B soil horizon mixed
Y - topsoil mixed with subsoil (C horizon) or topsoil absent
N - topsoil not mixed

3
+ - percentage higher than controls
- - percentage lower than controls
ND - no data

4
N - no change from control soils
- - firmer consistence than control soils
+ - looser

(Percent Difference from Controls[3])											
Stockpile Area			Working Area					Change in Topsoil Consistence[4]			
Live Cover	Height	Head	Live Cover	Height	Head	Trench Settlement	Increased Stones	Trench Area	Stockpile Area	Working Area	Comments
-29	+28	ND	<10	+57	ND	None	Yes	N	N	N	15 cm Csk on surface of stockpile. No topsoil on trench. Mixed topsoil on working area. Sage weeds and crested wheatgrass seeded.
-34	+220	ND	-32	+80	ND	None	Yes	N	N	N	10 to 15 cm mound subsoil on trench 45 cm. Csk on stockpile area. Topsoil removed from working area. Sage weeds.
-37	+140	ND	-49	+280	ND	None	No	-	-	N	Finer textured Csk on surface of all right-of-way, 5-15 cm deep. Trench subsoil looser. Sage weeds.
-87	+140	ND	-77	+160	ND	None	No	N	N	N	Looser subsoil in trench. Topsoil mixed on trench and stockpile. Sage weeds. Heavily grassed.
<10	+57	ND	-38	+28	ND	None	Yes	N	N	N	Looser subsoil in trench. Csk on surface of trench and stockpile areas. Mixed topsoil on working area. Crested wheatgrass seeded. Sage weeds.
-55	+260	ND	-32	+80	ND	None	No	N	N	N	25 cm mound subsoil on trench. Gopher holes. 10 cm. Csk on stockpile area. Topsoil removed on working area. Broom weed, sage weeds.
-54	+143	ND	-71	+28	ND	None	No	N	N	N	Finer textured Csk on trench and stockpile areas. Sage weeds.
-77	+60	ND	-84	+240	ND	None	No	N	N	N	Finer textured on surface. No topsoil on trench. Mixed topsoil on stockpile area. Sage weeds; heavily grazed.
-65	+80	ND	-55	<10	ND	None	Yes	-	-	-	Finer textured Csk on trench and stockpile areas. Topsoil removed on working area. Very weedy.
-49	+280	ND	-78	+200	ND	None	Yes	-	-	-	Finer textured Csk on all right-of-way. Crested wheatgrass seeded. Sage weeds.

4.2.4.1 Brown Chernozemic Soils

Effect on Soils

Topsoil was found to be absent over the trench at 7 of the 24 Brown Chernozemic soil sites. Three sites were located on sand dune areas with no topsoil available to replace. Two irrigated forage sites on Calcareous Brown Chernozemic soils had unmixed topsoil over the trench. The trenches of the remaining 12 sites had a mixture of topsoil and calcareous C horizon material over the surface. All of the annually cropped sites had mixed topsoil-C horizon material over the trench.

Topsoil mixing followed the same trend over the stockpile areas of all sites and working areas of the annually cultivated sites. Topsoil was mixed at fewer of the working areas under forage crops.

Where mixed or unmixed topsoil was found on the right-of-way, the depth varied from 5 to 43 cm. Topsoil depth varied on adjacent control areas from 12 to 25 cm except on the three Orthic Regosolic sand dune sites which had no topsoil.

Trench settlement was not evident at any of the sites. However, the irrigated annually cropped sites had experienced trench settlement (land owner comments) and additional backfilling was needed to facilitate flood irrigation. Mounding of soil and/or subsoil over the trench was most common on forage crop sites (71 percent of the sites) including 3 irrigated sites. The mounds ranged from 15 to 45 cm in height. Stoniness increased at only 8 percent of the Brown Chernozemic soil sites.

On many coarse textured sites, soil consistency was firmer or harder and as well, cloddy where topsoil was absent or mixed with finer textured subsoil. These changes in consistence were most common on the trench and stockpile areas (42 percent of the sites) but also occurred on the working areas (29 percent of the sites).

Effects on Vegetation

Three of the seven annually cropped sites had less than 10 percent change in live vegetation cover over the trench. These sites were all subject to flood irrigation and ranged from 12 to 23 years old. The other four sites, under fall rye, had a 38 to 48 percent decrease in cover over the trench.

Crop height decreased by 14 to 15 percent over the trenches at four of the seven sites, including the three flood irrigated sites. Height changed less than 10 percent over the trenches at two other sites and increased by 10 percent at one site. Head length decreased over the trenches at five of the seven sites, including only one of the three irrigated sites. The other two irrigated sites had less than 10 percent change in head length relative to controls.

The same trends in vegetation cover were apparent over the stockpile and working areas of the annually cropped sites. However, crop height decreased over the stockpile area and at all but one of the working areas. Head length was decreased over the stockpile and working areas at fewer sites than the decreases observed over the trenches.

Weeds were not generally present in increased amounts over the rights-of-way of annually cropped sites. The landowner at one irrigated

site noted that wild oats had been a problem on the right-of-way during the first two or three years after construction. Brome grass was noted over the trench at one irrigated barley site (22b).

Vegetation cover was decreased over the trench at 8 of the 17 crop sites and increased at 6 sites. There was less than 10 percent change in vegetation cover over the trenches of the three irrigated forage sites. The sites with increased cover over the trench included those native pasture sites with no topsoil where weedy species including foxtail barley, gumweed, sage, bluebur, wolf willow and wild rose predominate.

Vegetation height decreased over the trench at eight of the ten forage sites where data was available. Data was not taken at seven forage sites that had either been harvested or grazed prior to the field program.

The same trends were not as evident over the stockpile and working areas as over the trenches. Over the stockpile areas, fewer sites had increased cover and more had less than 10 percent difference from controls. Vegetation height over the stockpile areas decreased at fewer sites and was similar to adjacent control areas at more sites. Over the working areas, vegetation cover showed similar trends to the trench areas, but vegetation height decreased at fewer sites and was less than 10 percent different than controls at more sites.

Similar weedy species were prevalent over the trenches at all forage sites, but also were common on the stockpile and working areas except for wild rose and wolf willow.

Decreases in vegetation cover and/or height, on annually cultivated, Orthic Brown Chernozems appear to be the result of one or more of the following conditions:

- topsoil mixing; and
- possible nutrient tie up from the presence of lime.

Decreases in vegetation on annually cropped, flood irrigated Orthic Brown Chernozems appear to be the consequence of:

- topsoil mixing; and
- subsoil compaction.

The landowner also indicated that summer construction and location of the pipelines resulted in both short and long-term irrigation management difficulties. These included:

- inability to irrigate during season of construction;
- trench settlement diverts flood irrigation water and inhibits even distribution; and
- the location of the pipelines in the field makes the use of center pivot irrigation (needing buried water lines) difficult.

Decreases in plant cover and/or height on Brown Chernozemic soils under dryland improved and native pasture sites can be generally attributed to one or more of the following conditions:

- no topsoil salvage;
- calcareous parent material at the surface;

- mixing of topsoil and parent material over the stockpile and working areas; and
- lack of weed control following pipeline construction.

Expanded descriptions of sites experiencing crop decreases are presented in Appendix D.

4.2.4.2 Brown Solonetzic Soils

Effects on Soils

Topsoil was found to be mixed with C horizon material over the trench and stockpile areas of 78 percent of the annually cultivated Brown Solonetzic sites. Topsoil was unmixed over these areas at the remainder. The working areas had topsoil mixed with C horizon material at about half of the sites.

The depth of mixed or unmixed topsoil at the annually cultivated sites ranged from 10 to 25 cm compared to a range of 15 to 20 cm on the control soils. No trench settlement or mounding was observed at these sites. Surface soil stoniness and consistence were the same as control soils although finer topsoil texture was noted over the trenches at about half of the sites. Thirty-three percent also had looser soil at depth in the trench.

Topsoil was not salvaged at any of the native forage sites. Finer textured C horizon material with visible lime and salts was observed on the surface of all trenches and stockpile areas and on the working areas of 67 percent of the sites. The depth of C horizon material over the stockpile and working areas varied from 2 to 45 cm. A

10 to 25 cm mound of subsoil was found over the trench at 20 percent of the sites.

Effects on Vegetation

The crop cover over the entire right-of-way increased or showed less than 10 percent difference from controls at all five annually cultivated sites for which data was available. Cover data was not available at four sites where swathing commenced just prior to data collection. Barley or wheat crop height showed a similar increase or little change over the trench areas of the nine annually cropped sites. However, more sites had decreased crop height over the stockpile and working areas. Head length was generally the same over the rights-of-way as on the adjacent control areas. Weedy species were not generally present in increased amounts compared to adjacent control areas. Vegetation cover decreased over the trench and working areas at 13 of the 15 native forage sites and over the stockpile areas at 14 sites. Similarly, nearly all native forage sites had increased vegetation height. Corresponding to these trends is an abundance of a variety of weedy species over the entire right-of-way at all sites. Prevalent species included foxtail barley, sage, gumweed and broomweed. Native grasses were also present at most sites. Junegrass and spear grass were present on sites of all ages (7 to 23 years old) while native wheatgrass was less prevalent and blue gramma only occurred on the stockpile and working areas of one 23 year old site.

Decreases in percent live cover and/or crop height, on annually cropped Brown Solodized Solonetz appear to be due to:

- mixed topsoil and subsoil over very firm or hard subsoils (Bnt) on stockpile and working areas.

Decreases in crop characteristics on Solonetzic soils under native pasture are due to one or more of the following conditions:

- no topsoil replaced;
- topsoil mixed with Csk;
- subsoil left over working and stockpile areas;
- finer texture over right-of-way;
- gopher holes; and
- competition from weeds.

5.0 DISCUSSION AND CONCLUSIONS

The following section presents a discussion of the response of agricultural land under various types of soil and farming conditions to pipeline reclamation treatment.

5.1 Topsoil/Subsoil Salvage and Replacement

5.1.1 Topsoil Salvage

Topsoil was salvaged at approximately half (53 percent) of all sites examined and predominantly over the trench areas only (Figure 5.1). The highest proportion of sites where topsoil had been salvaged was in the Gray and Black Soil Zones and the lowest in the Brown Soil Zone (Table 5.1). Topsoil was salvaged at most (77 percent) annually cropped and irrigated sites, at about half of the dryland improved forage sites and at very few (9.5 percent) of the native pasture sites. There is little difference in the frequency of topsoil salvage between Chernozemic and Solonetzic soils for all sites.

From the limited information on depth of topsoil salvage it appears that where soil has been salvaged the depth varies from 10 cm to 45 cm. At the high end of the range at least some of the B horizon was salvaged together with the overlying topsoil.

5.1.2 Topsoil Replacement

A high proportion of sites (75 to 80 percent) had mixed topsoil and parent material or no topsoil on the surface of the trench and stockpile areas. The working areas often had this same mixing or

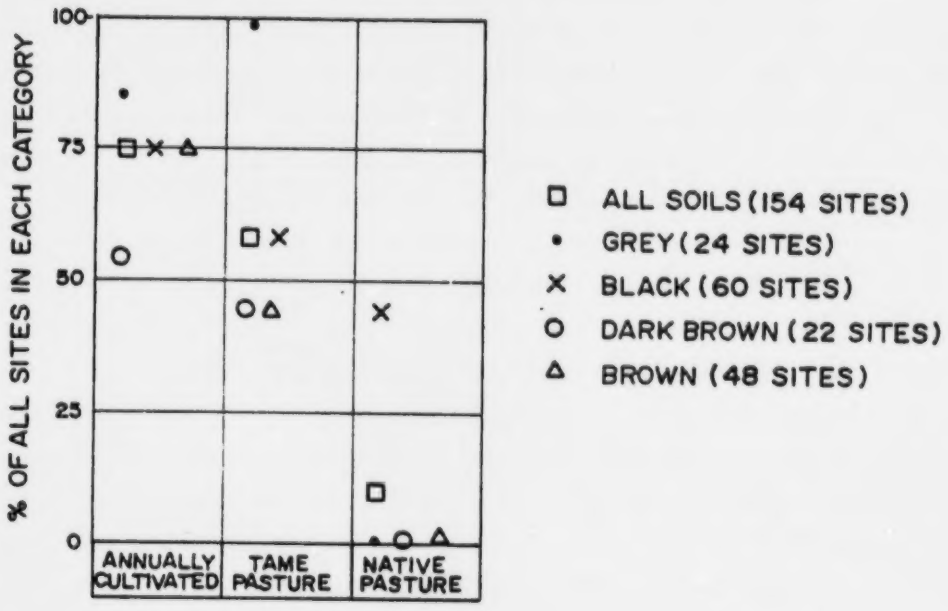


Figure 5.1
FREQUENCY OF TOPSOIL SALVAGE ON PIPELINE RIGHT-OF-WAY SITES INVESTIGATED IN ALBERTA

Table 5.1. Frequency (number of sites) of soil salvage and mixing on sites with Chernozemic and Solonetzic soils in Alberta.

Soil Zone Type	No. of Sites	Topsoil Salvaged	Topsoil Mixed with B and C at Surface[1]			Topsoil Absent or Buried by Subsoil			Topsoil Not Mixed			Topsoil Mixed with B Only			Number of Sites with Poorer Vegetation[2]			Number of Sites with Improved Vegetation[3]		
			T	S	W	T	S	W	T	S	W	T	S	W	T	S	W	T	S	W
Gray Luvisolic																				
Cultivated	11	11	4	5	5	0	0	0	1	1	3	6	5	3	7	8	9	2	1	0
Tame Pasture	5	5	0	0	0	0	0	0	2	2	3	3	3	2	3	3	0	0	1	2
Native Pasture	4	0	3	4	0	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Gray Solonetzic																				
Cultivated	3	1	0	0	0	2	2	2	1	1	1	0	0	0	1	2	2	1	1	1
Tame Pasture	1	1	0	0	1	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0
Black Chernozem																				
Cultivated	23	18	17	13	4	1	0	2	4	9	16	1	1	1	4	4	5	6	6	6
Tame Pasture	13	8	2	10	4	4	0	3	0	0	6	0	3	0	5	5	5	1	0	0
Native Pasture	9	4	7	6	5	0	1	1	2	2	3	0	0	0	7	6	6	0	0	0
Black Solonetzic																				
Cultivated	9	6	8	6	4	0	0	0	1	3	5	0	0	0	5	6	5	2	2	2
Tame Pasture	6	3	4	6	2	0	0	0	1	0	4	1	0	0	3	5	3	1	0	0
Dark Brown Chernozemic																				
Cultivated	8	5	8	7	3	0	0	0	0	1	5	0	0	0	7	3	3	0	2	1
Irrigated Cultivated	1	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0
Tame Pasture	4	1	1	2	1	3	2	0	0	0	3	0	0	0	4	2	4	0	1	0
Native Pasture	4	0	2	1	0	2	3	1	0	0	3	0	0	0	4	4	0	0	0	2
Irrigated Pasture	1	0	1	1	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0
Dark Brown Solonetzic																				
Tame Pasture	4	3	4	4	2	0	0	0	0	0	2	0	0	0	2	3	2	2	1	2
Brown Chernozemic																				
Cultivated	4	0	4	4	4	0	0	0	0	0	0	0	0	0	4	4	4	0	0	0
Irrigated Cultivated	3	3	3	3	3	0	0	0	0	0	0	0	0	0	3	3	3	0	0	0
Tame Pasture	4	0	4	4	4	0	0	0	0	0	0	0	0	0	3	4	4	1	0	0
Irrigated Pasture	3	3	1	1	0	0	0	0	2	2	3	0	0	0	0	0	0	0	0	0
Native Pasture	10	0	0	2	1	7	5	2	3	3	7	0	0	0	8	7	8	2	2	2
Brown Solonetzic																				
Cultivated	9	9	7	7	4	0	0	0	2	2	5	0	0	0	1	5	4	4	2	2
Native Pasture	15	0	1	2	4	14	13	8	0	0	3	0	0	0	15	15	14	0	0	0
Total - Chernozemic/ Luvisolic Soils																				
Cultivated	46	34	33	29	16	1	0	2	5	11	24	7	6	4	22	19	21	8	9	7
Irrigated Cultivated	4	3	4	4	4	0	0	0	0	0	0	0	0	0	4	4	4	0	0	0
Tame Pasture	26	14	13	16	9	7	2	3	3	2	12	3	6	2	15	14	13	2	2	2
Irrigated Pasture	4	3	2	2	0	0	0	0	2	2	4	0	0	0	1	1	0	0	0	0
Native Pasture	27	4	12	13	6	10	9	4	5	5	17	0	0	0	19	17	14	2	2	4
	107	58	64	64	35	18	11	9	15	20	57	10	12	6	61	55	52	12	13	13
Total - Solonetzic Soils																				
Cultivated	21	16	15	13	8	2	2	2	4	6	11	0	0	0	7	13	11	7	5	5
Tame Pasture	11	7	8	10	5	0	0	0	1	0	6	2	1	0	6	9	6	3	1	2
Native Pasture	15	0	1	2	4	14	13	8	0	0	3	0	0	0	15	15	14	0	0	0
	47	23	24	25	17	16	15	10	5	6	20	2	1	0	28	37	31	10	6	7
Total - All Soils																				
Cultivated	67	50	48	42	24	3	2	4	9	17	35	7	6	4	29	32	32	15	14	12
Irrigated Cultivated	4	3	4	4	4	0	0	0	0	0	0	0	0	0	4	4	4	0	0	0
Tame Pasture	37	21	21	26	14	7	2	3	4	2	18	5	7	2	21	23	19	5	3	4
Irrigated Pasture	4	3	2	2	0	0	0	0	2	2	4	0	0	0	1	1	0	0	0	0
Native Pasture	42	4	13	15	10	24	22	12	5	5	20	0	0	0	34	32	28	2	2	4
	154	81	88	89	52	34	26	19	20	26	77	12	13	6	89	92	83	22	19	20

[1] T - trench area
S - stockpile area
W - working area

[2] More than 10 percent lower cover and/or height or increase in weeds.

[3] More than 10 percent greater cover and/or height. No increase in weeds.

absence of topsoil although not as frequently (46 percent) as over the trench and stockpile areas.

Mixed topsoil and C horizon was observed most frequently over the trenches (74 to 88 percent of all sites), less frequently over the stockpile areas and least frequently over the working areas (42 to 52 percent of all sites) for annually cultivated sites. On improved and native forage sites, the stockpile areas had the same frequency of topsoil and C horizon mixing or absence as over the trench areas. Native pasture sites which had the lowest frequency of topsoil salvage had the highest frequency of absence of topsoil over the trench, and burial or loss of topsoil over stockpile and working areas.

Only 20 of the 154 sites (13 percent) examined had topsoil replaced over the trench unmixed with subsoil. A similar proportion of the total sites had unmixed topsoil over the stockpile areas while half of the 154 sites had unmixed topsoil over the working areas, taking into account that three of the native pasture sites in the Brown Soil Zone were Orthic Regosols, and were included in the unmixed topsoil category (there is little or no topsoil present in this soil type). Approximately equal proportions of Chernozemic and Solonetzic soil sites had unmixed topsoil over the trenches. A slightly higher proportion of Chernozemic sites had unmixed topsoil over the stockpile and work areas. Unmixed topsoil was found at a higher proportion of annually cultivated sites than improved or native pasture sites.

Mixed topsoil and subsoil (B horizon) was found in 50 percent of the cultivated and improved forage sites in the Gray Luvisolic soils

over the trench and stockpile areas. This was also found less frequently on Solonetzic soils in the Gray Soil Zone and on Black Chernozemic soil sites.

Conclusions

It is evident that, even though topsoil was salvaged at many sites, thorough mixing with subsoil (B horizon) and parent material (C horizon) still occurred. This result was also observed by Culley et al. (1981) along an oil pipeline in Ontario. Mixing was observed over the trench and stockpile areas but also less frequently over the working area. This trend is most common on annually cultivated sites and on the improved pasture sites. Topsoil was rarely salvaged at native pasture sites and, consequently, the loss or mixing of topsoil is expected. All of the irrigated annually cropped sites had mixed topsoil over the entire right-of-way.

Where topsoil has been salvaged and observed to be absent or mixed, several potential causes are evident.

1) Stockpiling method and backfilling equipment. The most common method of stripping topsoil is to place the topsoil on the outside of the subsoil stockpile area (Figures 4.3 and 4.6). Backfilling with the use of a "Mormon Board" (Figure 4.2) or bulldozer is conducive to topsoil mixing. To a large degree the extent of topsoil mixing will be dependent on the equipment operator's experience, accuracy and care. The high frequency of mixed topsoil over the trenches and stockpile areas is likely the result of this combination of stockpiling method and backfilling equipment.

2) Incomplete backfilling of spoil material. Spoil material (B and C horizon) may not be completely backfilled either because it is in excess (due to bulking or pipe size) or because of the type of equipment commonly used for backfilling (see 1 above). The effects of this are frequently observed where either mixed topsoil and spoil or a layer of predominantly C horizon material (5-10 cm thick) is found on the surface of the stockpile area overlying the original topsoil. On the few sites where topsoil was salvaged over the stockpile area as well as the trench (Figure 4.4) there was a higher frequency of unmixed topsoil found over the stockpile areas.

3) Disposal of excess spoil material. It is evident that excess spoil disposal is a possible concern. The excess, when it occurs, appears to have been spread evenly over the working and stockpile areas on small and large diameter pipelines. The excess may be either the result of soil bulking and/or of large pipe diameter. The layer of spoil material found on working area surfaces rarely exceeded 10 cm in thickness. The evidence for the subsoil layer over the working area surface was greatest on improved and native pasture sites. Mixing with underlying topsoil generally occurred on annually cultivated sites. On irrigated annually cultivated sites, the additional soil disturbance during rebackfilling after trench settlement and leveling likely enhanced the mixing. However, the additional equipment working on the right-of-way may have led to the compaction of the soil below the plow layer.

4) Topsoil salvage depth. Although information on the depths of topsoil salvaged is limited, the maximum soil salvage depth at sites in this study was 45 cm. This included topsoil and B horizon material. The reasons for this salvage depth are not evident.

However, where salvage depth exceeds topsoil depth mixing of topsoil and B horizon will occur, especially in the Black and Gray soil zones. Where B horizons are shallower or in soil types where B horizons are absent, deep salvage of soil material could also encourage mixing of topsoil and parent material (C horizon).

5.2 Vegetation Responses

5.2.1 Annual Crop Response to Soil Salvage and Replacement

Forty-four percent of the annually cultivated sites had crops which were thinner (more than 10 percent less cover), shorter, and/or weedier than adjacent control areas (Figure 5.2). Poorer crops were found in approximately equal proportions on the working areas of Solonetzic and Chernozemic sites (Figures 5.3 and 5.4). There were fewer trenches and more stockpile areas with poorer annual crops at Solonetzic sites. The magnitude of the change can be greater on some Solonetzic soils where saline parent material has been left on, or mixed into the surface soil layer.

Poorer annual crops were least common in the Black Soil Zone and on trench areas in Brown Solonetzic soils (Figures 5.5 and 5.6). In the Black Soil Zone this is possibly the result of less severe topsoil/subsoil mixing, and less moisture deficiency. In the Brown Solonetzic soils, where moisture deficiency is more common, only one of the nine sites had a poorer crop cover over the trench. This appears to be the result of improved physical conditions of the soil allowing deeper root penetration, higher soil moisture storage and use. This effect is evident even though the replaced soil was mixed with subsoil at most sites. However, on the non-trench areas of the Solonetzic sites

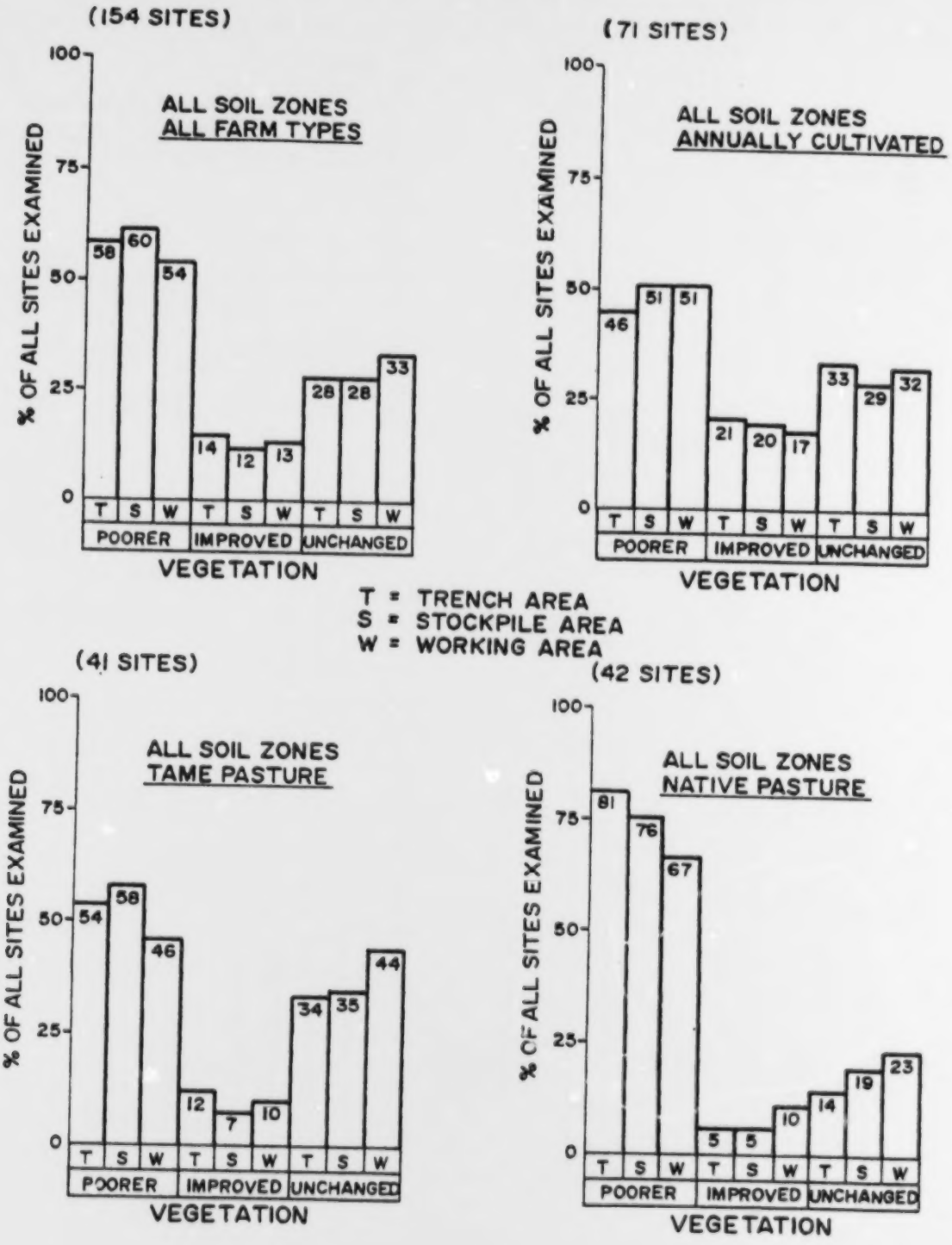


Figure 5.2
VEGETATION CHANGES ON RIGHT-OF-WAY SITES INVESTIGATED IN ALBERTA

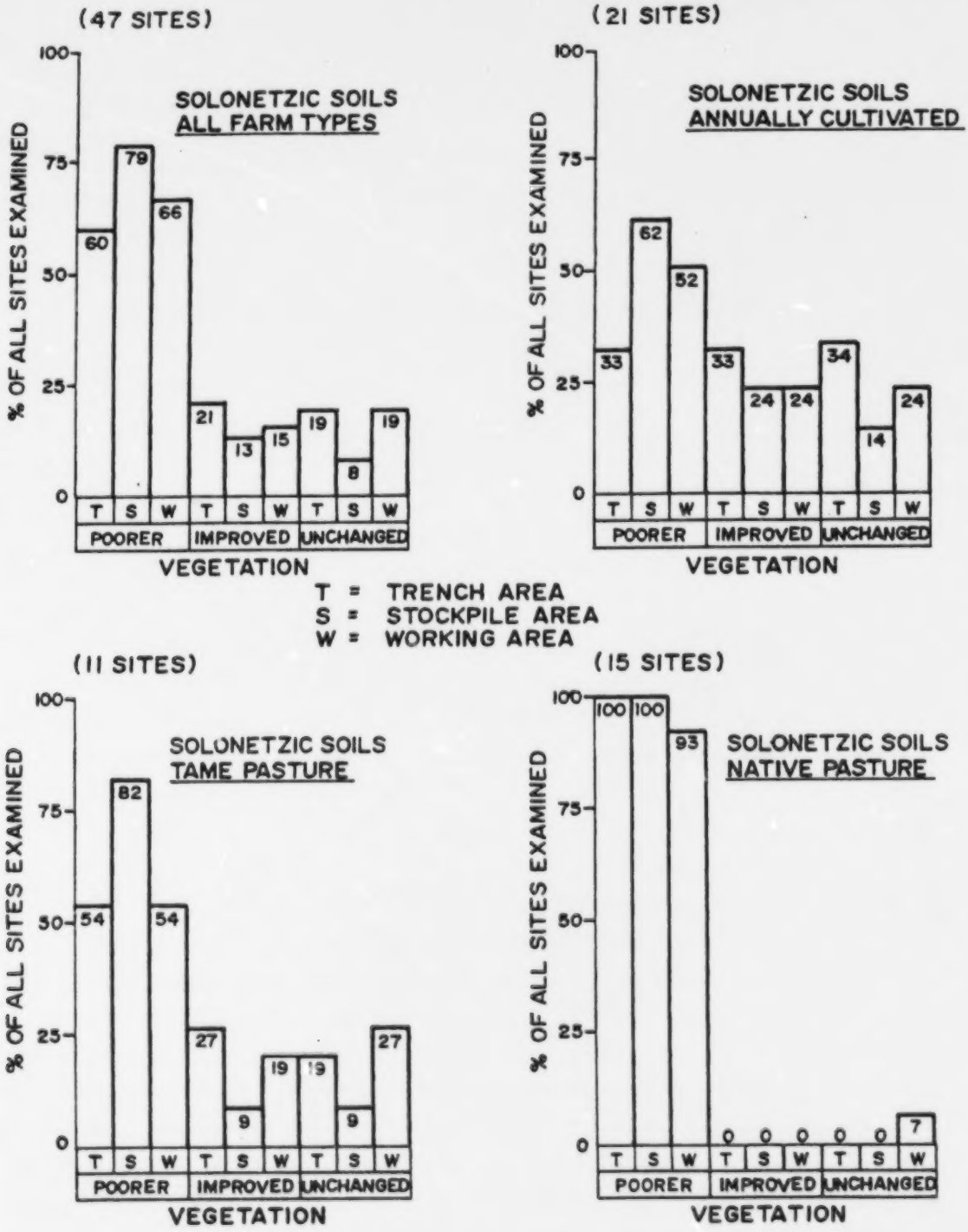


Figure 5.3
VEGETATION CHANGES ON PIPELINE RIGHT-OF-WAY SITES INVESTIGATED ON SOLONETZIC SOILS IN ALBERTA

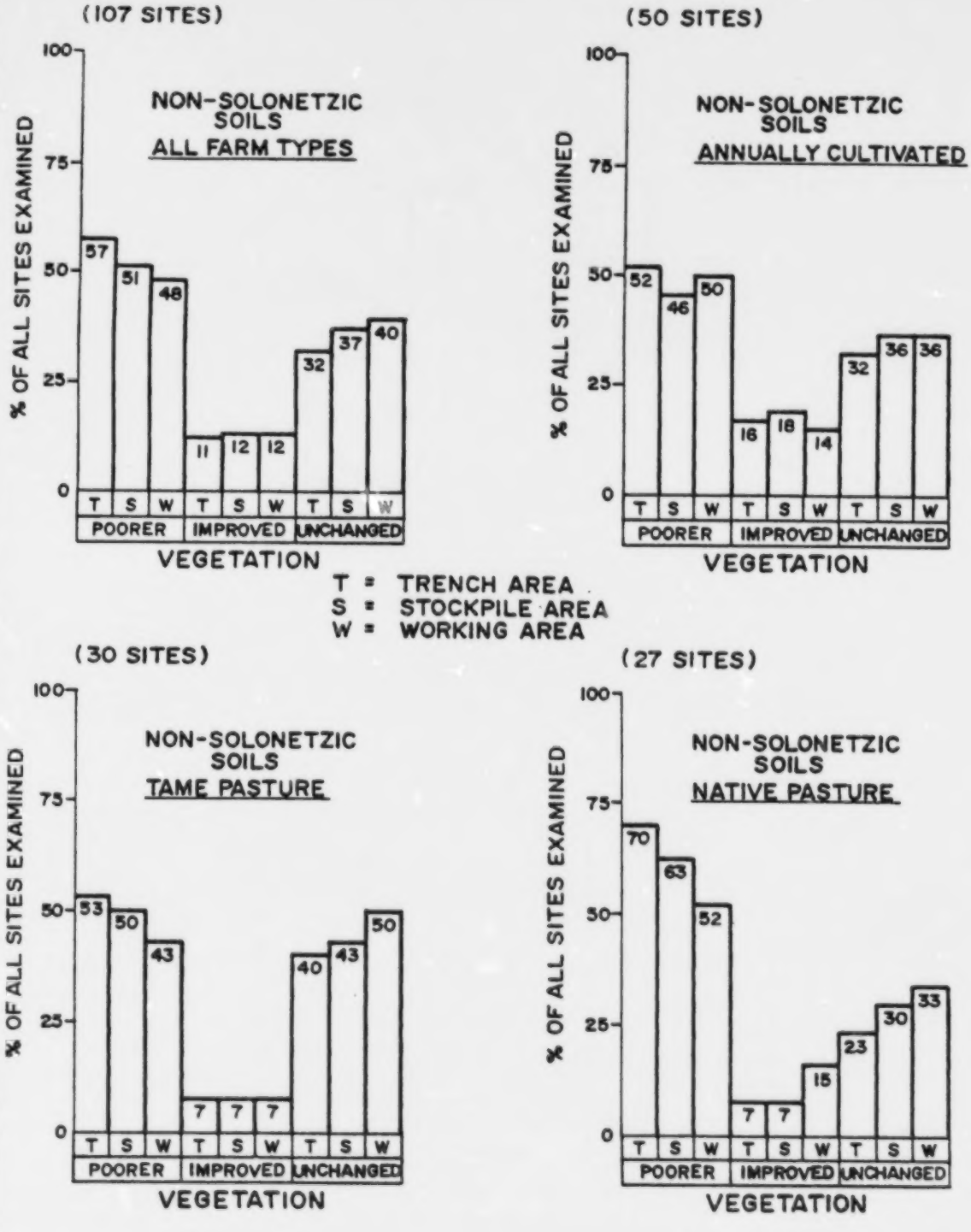


Figure 5.4
VEGETATION CHANGES ON PIPELINE RIGHT-OF-WAY SITES INVESTIGATED ON NON-SOLONETZIC SOILS IN ALBERTA

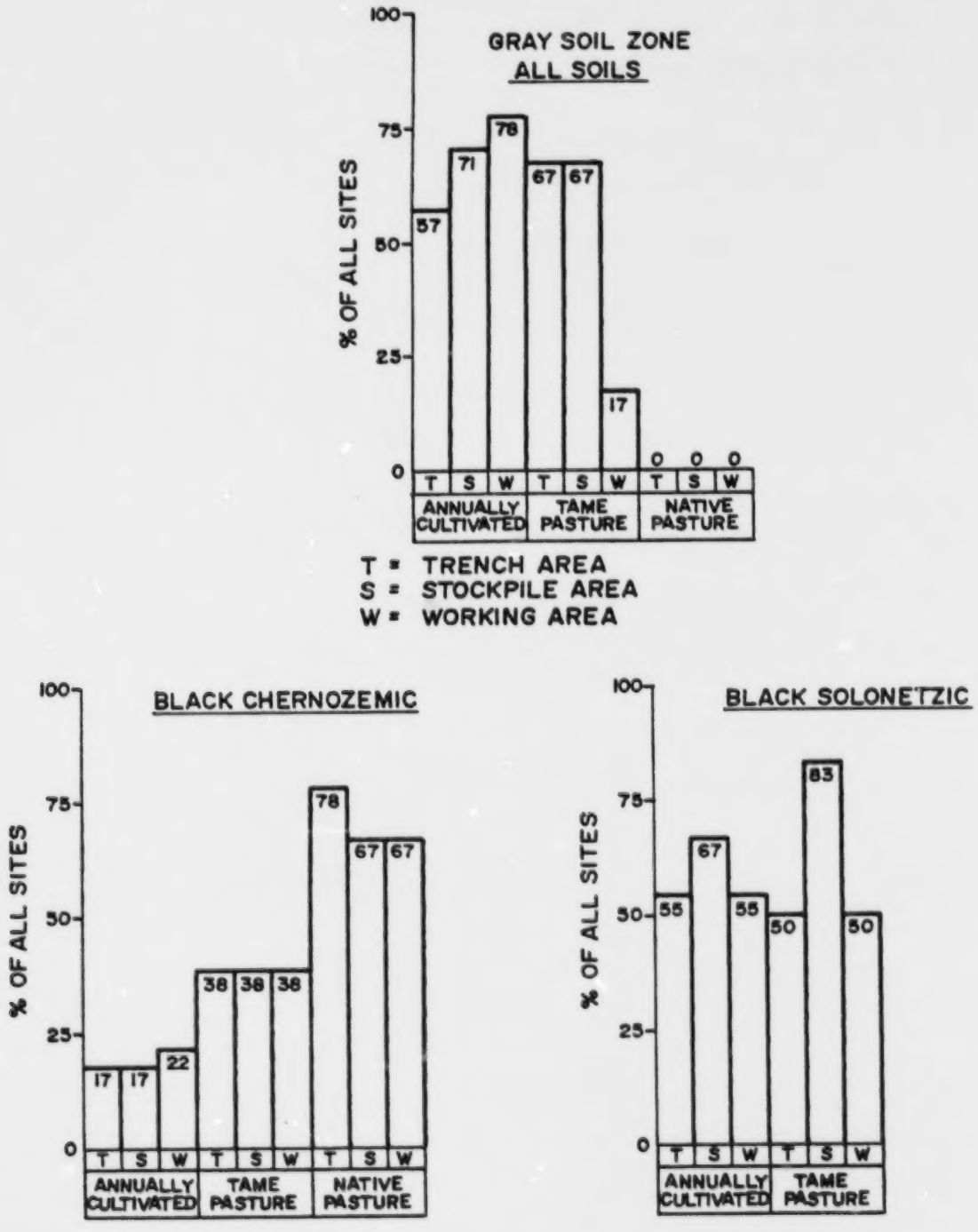


Figure 5.5
RELATIVE FREQUENCY OF POORER ANNUAL CROPS, TAME PASTURE AND NATIVE PASTURE ON PIPELINE RIGHT-OF-WAY SITES INVESTIGATED IN TH BLACK AND GRAY SOIL ZONES IN ALBERTA

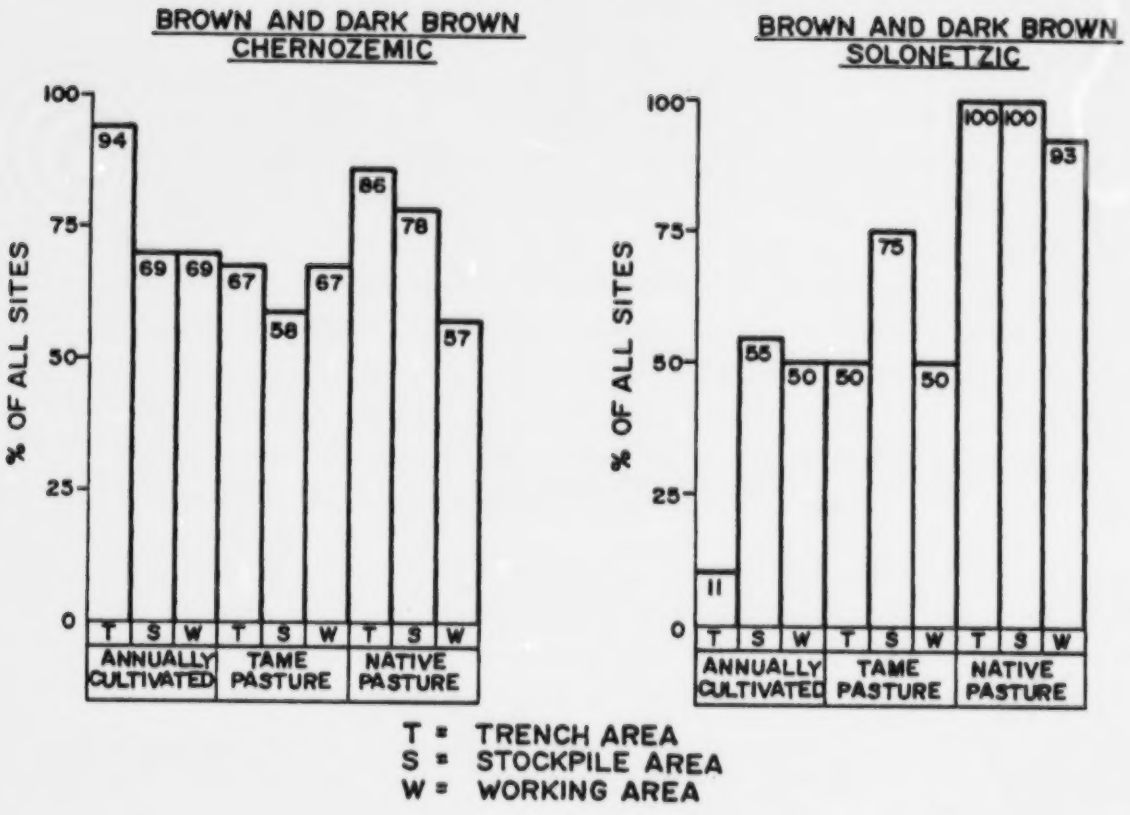


Figure 5.6
RELATIVE FREQUENCY OF POORER ANNUAL CROPS, TAME PASTURE AND NATIVE PASTURE ON PIPELINE RIGHT-OF-WAY SITES INVESTIGATED IN THE BROWN AND DARK BROWN SOILS IN ALBERTA

where subsoil structure was not loosened by trenching, there was a general trend to a higher frequency of sites with poorer crops. This trend appears to be the result of either mixed topsoil or subsoil being left on the surface.

Little trend in crop response between annual crops is apparent. Canola, however, did not appear to be as sensitive to soil changes as wheat, barley, oats and fall rye.

All four irrigated, annually cropped sites had poorer crop growth corresponding to the mixed topsoil and compacted subsoil conditions over the right-of-way.

5.2.2 Improved Forage Crop Response to Soil Salvage and Replacement

Fifty-four percent of all improved forage sites had more than 10 percent reduction in live cover, height and/or increase in weeds over the trenches (Figure 5.2). Similar trends were evident over the working and stockpile areas. The frequency of poorer forage crops was similar on Chernozemic and Solonetzic soils and in all soil zones except on stockpile areas of Solonetzic sites where 82 percent of the sites had poorer crops. Increased weediness was a recurring feature at many improved forage sites. This is likely the result of the competitive advantage weedy species have during revegetation, particularly under poorer soil conditions where topsoil has been mixed or buried. Where improved forage has been managed and cut annually weeds are less frequent. Under pasture use the weedy species have persisted on the rights-of-way over pipelines as old as 24 years.

The three irrigated Brown Chernozemic forage crop sites had similar crop cover, height and weed abundance to the adjacent areas. This corresponds to the unmixed topsoil found on two of the three trench and stockpile areas, and mixed topsoil and subsoil found on the third site. It is likely that annual cutting and weed control also assisted in providing even forage stands at these sites.

5.2.3 Native Pasture Response to Soil Salvage and Replacement

Eighty-one percent of all native pasture sites had more than 10 percent reduction in live cover, height, and/or increase in weeds over the trenches (Figure 5.2). Similar trends were evident over the stockpile and working areas (76 percent and 67 percent, respectively). Topsoil was salvaged at 10 percent of the sites and unmixed topsoil was found over the trench and stockpile areas in similar proportions. Soil was unmixed over the working areas at about half of the native pasture sites. The majority of sites with unmixed topsoil were Black or Gray non-Solonetzic soils.

As with the improved forage sites, increased weediness was a recurring feature at most native pasture sites, likely the result of the competitive advantage of weedy species under poor soil conditions.

On a few native pasture sites, revegetation with grass species different from the adjacent field have resulted in pasture management difficulties. This was evident where timothy was dominant over rights-of-way through native fescue pasture used for winter grazing. Timothy is less palatable than native species for winter grazing and these areas were consequently unused. Conversely, where similar pastures are used

for summer grazing Timothy is preferentially grazed. The result is often heavy traffic over the right-of-way, soil disturbance, and regeneration with a dominance of weedy species.

5.3 Effects of Age of Pipeline and Season of Construction

On annually cultivated sites in the Black and Gray Soil Zones poorer crops were found on sites from 1 to 22 years old, however, the crops at the majority of sites older than 3 years were either similar to or improved over adjacent control areas. In the drier Brown and Dark Brown Soil Zones poorer annual crops were more common on sites up to 23 years old.

The crop response in Solonetzic soils may persist longer than in Chernozemic soils both where the crop is poorer and improved.

On improved and native forage sites poorer crops and weedier conditions were found on all ages of pipeline in all zones. Weedy species were most visible on the native pasture sites in the Brown Soil Zone where their height and form contrasted with adjacent grass species and on sites in other zones where Canada thistle was dominant. Where topsoil salvage was conducted during winter pipeline construction results are similar to summer operations.

5.4 Topsoil Mixing and Crop Response

It is evident from the results that even though topsoil has been mixed with subsoil (C horizon) at many sites this does not always result in poorer crops. This is particularly evident in the Black Soil Zone and under annually cultivated conditions. While this trend appears

to be the result in part of moisture availability and age as previously discussed it is likely also a function of the degree of mixing, and the resultant magnitude in changes in key topsoil quality factors including texture, organic matter content, salinity and/or sodicity, and calcium carbonate equivalent. Limits for these factors may need definition in future studies to determine levels beyond which poorer crops may persist. On improved and native forage sites poorer crops appear to be in large part the result of increased weediness which is enhanced where topsoil is mixed, lost or buried. From the results it appears that even a thin 5 to 10 cm layer of C horizon material on the surface will provide a competitive edge to weedy species during revegetation and that these species will persist over time unless controlled by management practices. A combination of improved soil salvage and replacement and weed control practices would improve this result.

5.5 Effects on Irrigation Practices

Soil settlement over the trench and subsoil (B horizon) compaction were most evident at irrigated sites. Settlement results in the need for additional backfilling to provide the critical level surface needed for even distribution of irrigation water. The additional traffic on the right-of-way during rebackfilling may cause the subsoil compaction observed.

The quality of the backfill material and levelling done during backfilling and rebackfilling may also affect the quality of the soil over the right-of-way surface. On all of the annually cropped, irrigated sites observed the topsoil was mixed with C horizon material

and thinner and/or shorter crops were evident. The same mixing was not as prevalent on irrigated forage sites and the crop cover was similar to adjacent areas.

According to the landowners and managers other disruptions also occur on irrigated land including loss of at least one cropping season when the pipelines are constructed in summer and restriction of the types of irrigation methods that can be used after pipeline construction.

6.0 RECOMMENDATIONS

The following recommendations are provided for the purpose of minimizing disruption of agricultural lands from pipeline installation. The recommendations are grouped into five categories:

- preconstruction planning;
- construction;
- post construction reclamatior;
- other general recommendations; and
- additional studies.

As many of the recommendations are specific to soil zone, type and farm practice, each recommendation is numbered. The situation to which each recommendation applies is then shown by recommendation number in Table 6.1.

If information becomes available from the additional survey and research studies recommended, particularly related to solonetzic and irrigated soils and winter handling of topsoil, the recommendations currently proposed could be made with greater confidence or modified as needed.

6.1 Recommendations for Preconstruction Planning

Refer to Table 6.1 for soil zone and farm practice to which each of the following recommendations is applied.

1. Conduct soil survey to identify topsoil depths, erodible areas and soil characteristics which may influence soil handling and

Table 6.1. Recommendation numbers (see text) for soil zone and farm practice.

Soil Zone/Type	Preconstruction	Construction	Reclamation	Others	Additional Studies
Gray Luvisolic					
- cultivated	1-3, 5, 6	9-15, 19-20	21-23	30-34	38
- tame pasture	1, 4, 7, 8	16	22-26, 28	30-34	
- native pasture	1, 4, 7, 8	16	27-29	32, 33	
Gray Solonetzic					
- cultivated	1-3, 5, 6	9-15, 17, 19-20	21	30-34	35, 38
- tame pasture	1-3, 5-8	9-15, 17, 19-20	21	30-34	35, 38
Black Chernozem					
- cultivated	1-3	11-15, 18-20	21	30, 32-34	38
- tame pasture	1-3, 5-9	9-15, 19-20	21-23, 25-26, 28	30-34	38
- native pasture	1, 2, 7, 8	9-15, 19, 20	29	30-34	38
Black Solonetzic					
- cultivated	1-3, 5, 6	9-15, 17, 19-20	21	30-34	35, 38
- tame pasture	1-3, 5-8	9-15, 17, 19-20	21-23, 25-26, 28	30-34	35, 38
Dark Brown Chernozem					
- cultivated	1-3, 5, 6	9-15, 19-20	22-23	30-34	36, 38
- irrig. cultivated	1-3	9-17, 19-20	21-24	30-34	36, 38
- tame pasture	1-3, 5-8	9-15, 19-20	21-23, 25-26, 28	30-34	36, 38
- irrig. pasture	1-3, 7, 8	9-17, 19-20	21-26, 28	30-34	36, 38
- native pasture	1-3, 7, 8	9-13, 19-20	29	30-34	36, 38
Dark Brown Solonetzic					
- tame pasture	1-3, 5-8	9-15, 17, 19-20	21-23, 25-26, 28	30-34	35, 36, 38
Brown Chernozem					
- cultivated	1-3	9-13, 19-20	22-23	30-34	36, 38
- irrig. cultivated	1-3, 5	9-17, 19-20	21-24	30-34	36, 38
- tame pasture	1-3, 7, 8	9-13, 19-20	22-23, 25-26, 28	30-34	36, 38
- irrig. pasture	1-3, 5-8	9-17, 19-20	21-26, 28	30-34	36, 38
- native pasture	1-3, 5-8	9-13, 19-20	21-23, 26-29	30-34	37, 38
Brown Solonetzic					
- cultivated	1-3	9-13, 17, 19-20	21	30-34	35, 36, 38
- native pasture	1-3, 7, 8	9-13, 17, 19-20	21-23, 26, 28	30-34	36, 38

replacement. Identify the particular location of Solonetzic soils, depth of topsoil, and depth to and salinity/sodicity levels of the parent material within the trench depth.

2. On the basis of texture and organic matter, data from preconstruction soil surveys provide an indication of the feasibility of winter topsoil salvage. This interpretation will assist planners in scheduling topsoil salvage for fall or winter and deciding if special equipment is needed.

3. Plan to salvage topsoil and replace to depths as defined by soil survey.

4. Selective topsoil salvage and replacement should be considered but may not generally be needed.

5. Plan and conduct drainage contouring or levelling in conjunction with land owner/manager.

6. Where surface drainage of poorly drained areas is not possible, consider revegetating with flood tolerant species.

7. Select revegetation species on basis of compatability with surrounding pasture and landowner needs.

8. Review specific reclamation and revegetation plans with pasture manager/landowner during preconstruction planning and modify as needed.

6.2 Recommendations for Pipeline Construction

Refer to Table 6.1 for soil zone and farm practice to which each of the following recommendations is applied.

9. Separate topsoil and spoil stockpiles by 0.5-1 m and where possible, on opposite sides of trench.

10. Where possible, salvage topsoil from trench and stockpile areas.

11. Replace topsoil to same depths as occurred prior to construction.

12. Avoid if possible, handling topsoil under wet conditions.

13. If excess spoil is present, dispose offsite in an acceptable manner or level over trench and stockpile area where topsoil has been previously removed. If extra area is needed on which to level excess spoil, remove topsoil first. Replace topsoil after all excess spoil has been removed or levelled.

14. Where drainage contouring or levelling is needed, salvage topsoil rough contour then replace topsoil.

15. Restrict or curtail vehicle and machinery traffic on right-of-way during wet conditions.

16. Ensure that backfilled spoil is compacted by bulldozer or rubber tired vehicle to minimize settlement.

17. Maintain strict supervision and control to ensure compliance with recommended topsoil salvage, spoil disposal, and topsoil replacement.

18. Salvage topsoil over trench area. Stockpile topsoil separate from spoil, backfill spoil followed by topsoil.

19. For winter construction, topsoil salvage should be conducted during winter or late fall. The feasibility of winter salvage will generally improve if topsoil is relatively dry at freezeup, particularly on coarser soils, and during early winter when frost penetration is still limited to the topsoil. Preripping frozen topsoil has also been used with some success during winter salvage.

20. Backfilling and topsoil replacement can also be conducted in winter (and may be preferred for wet or moist fine textured soils). Any large lumps of soil should be broken up by passing a bulldozer or other heavy equipment over them during replacement. Smaller lumps of topsoil will break up naturally during spring thaw. During winter backfilling and topsoil replacement care should be taken to minimize the amount of snow placed in the trench, (see recommendation No. 38).

6.3 Recommendations for Post Construction Reclamation

Refer to Table 6.1 for soil zone and farm practice to which each of the following recommendations is applied.

21. In areas where topsoil has been compacted cultivate as needed. In areas where subsoil has been excessively compacted (particularly on

irrigated areas) deep cultivation may be warranted even though some topsoil/subsoil mixing may occur.

22. Monitor right-of-way for two to three years following construction to determine site specific need for weed control.

23. If weed control is needed, plan and implement measures in conjunction with landowner and weed control specialist.

24. Where trench settlement occurs rebackfill with topsoil (if available) of similar quality to that in surrounding field so that right-of-way surface is level in cross section. Avoid rebackfilling during wet conditions.

25. Use fertilizer at rates determined following soil nutrient tests to encourage reestablishment of pasture.

26. If possible, restrict grazing or cutting on seeded right-of-way until forage has established (usually one to three growing seasons depending on site condition). Provide temporary fencing as needed.

27. Use slash or other methods as needed for erosion control in moderate to high erosion risk areas.

28. Revegetate with grass/legume species that are compatible with the pasture management objectives.

29. Fertilize at rates determined following soil tests in areas where rapid revegetation for erosion control is needed.

6.4 Other General Recommendations

Refer to Table 6.1 for soil zone and farm practice to which each of the following recommendations is applied.

30. Standby equipment should be available the spring following winter construction to either level trench mounds that have not settled or backfill trenches that have settled below the original surface. Additional backfilling material used should be topsoil of similar quality to the surrounding area.

31. In order to conserve topsoil, operator accuracy should be maintained and enhanced. This can in part be accomplished by the presence of environmental inspectors, and the insertion of reclamation procedures and standards in the reclamation contract bid offer. Equipment such as power dozers and/or graders which allow the greatest soil handling accuracy should be used for both salvaging and backfilling of topsoil (see Section 4.1.1.3).

32. The inspection of reclamation implementation commencing during salvage operations and continuing through replacement and revegetation is suggested.

33. It is recommended that "as built" reclamation methods and results be documented for individual pipelines. This will provide data for improving reclamation techniques in the future. The level of detail needed should be developed with industry but could include details of topsoil salvage methods, accuracy controls, topsoil replacement depths, methods used in unusual soil conditions (sand dunes, wet areas, Solonetzic soils).

34. Stones in excess of what occurs on undisturbed areas, should be removed from the plow layer.

6.5 Recommendations for Additional Study

Refer to Table 6.1 for soil zone and farm practice to which each of the following recommendations is applied.

35. Additional study is needed to define the tolerance limits of cultivated cropland to the mixing of topsoil and subsoil. Particular emphasis may be placed on organic matter, carbonate, salinity levels, and soil physical properties, such as moisture holding capacity and aggregate stability in the mixed topsoil/subsoil beyond which crop growth is reduced. Also examine the relative benefits and costs of ameliorating mixed soil/subsoil with soil amendments compared to increasing the accuracy of topsoil salvage.

36. The current efforts by industry to develop more accurate soil salvage and replacement equipment should be continued and given priority for application in areas of thin, sensitive topsoil (i.e. Brown and Dark Brown Soil Zones).

37. Encourage the continuance of industry field trials and other studies designed to improve seed bed characteristics and soil microenvironment conditions so that better revegetation of sandy wind erodible soils may be achieved.

38. Further research regarding winter construction versus summer construction, and acceptable methods for winter operations are suggested.

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APPENDIX A

Characteristics of Sites With Decreased Vegetation - Gray Soil Zone

Decreases in percent live cover and/or plant height were detected on sites with the following characteristics:

a) Sites 76a, 76b, 77a and 77b. These sites are all over a winter constructed water pipeline with a first year cover of barley. Topsoil was salvaged over the entire right-of-way including a 7 year old parallel line. Parent material (Ck horizon) was mixed with replaced topsoil over the whole right-of-way. This mixing resulted in a decrease of organic matter (7.4 percent to 2.7 percent), and NO_3-N (6 to 2.5 ppm). Increases observed were in $CaCO_3$ equivalent (0.5 to 1.6 percent), pH (6 to 7.5) and sulphate-sulphur (4 to 20 ppm). Electrical conductivity (0.2 to 0.4), available phosphorus (6 to 8 ppm) and available potassium (110 to 145 ppm) were relatively unchanged from control soils. The mixed topsoil was replaced in depths of 7 to 15 cm compared to 13 to 19 cm for control soils. Contouring of drainageways was conducted after topsoil replacement resulting in little or no topsoil in these locations. The poorest growth occurred in this situation and the best growth occurred where replaced topsoil was deepest. Trends are not specific to trench, stockpile or working area. Cracking and crusting of silty clay loam to silty clay textured soil was evident over the trench in one small ponding area. Decreases in growth appear to the the result of:

- extensive mixing of topsoil with parent material;
- shallow topsoil replacement depth;
- loss of topsoil on contouring of drainageways; and
- cracking and crusting in an area of water ponding.

b) Site 63. This 2 year old 508 mm diameter pipeline is seeded to wheat. The topsoil and B horizon were salvaged from the trench, stockpile and working areas. The replaced topsoil on the stockpile and working areas were mixed with B horizon materials and calcareous parent material, however, little or no parent material was evident in the topsoil over the trench. The depth of replaced topsoil was 28 to 58 cm compared with 20 cm of topsoil depth in control soils. Twenty-six percent less cover of wheat was evident on the stockpile and working areas while over the trench there was less than 10 percent difference in cover. Differences in plant height and head length throughout the rights-of-way were less than 10 percent. Decreases in growth appear to be the result of extensive mixing of topsoil with B horizon and parent material.

c) Site 82. This 9 year old summer constructed 508 mm diameter gas pipeline was seeded to a barley crop. Topsoil was salvaged from the trench area and replaced to depth of 15 cm. The replaced soil was mixed with the B horizon on the trench and stockpile areas only. The vegetation cover was 30 percent lower on the stockpile areas only as compared to the undisturbed areas. Over the trench, increased height and head length was observed while no change in crop growth was apparent on the working areas except for an increased cover of Equisetum weeds. Stones appeared to have increased on the surface of the trench. The reason for decreased crop cover over the stockpile area was not readily apparent.

d) Sites 75b, 75c and 75d. These sites occur on pipelines constructed in the summer, varying in age from 5 to 19 years. The current cover is grass/legume mixture. Topsoil was salvaged and replaced to depths of 10 to 15 cm, however, when replaced, the topsoil was

generally mixed with the B horizon. Trench settlement of 10 to 15 cm and an increase in surface stoniness over the trench occurred at these sites. There also appeared to be more gopher and badger holes and Canada thistle over the trenches than on the controls.

Differences in crop height of 25 to 35 percent lower than the controls occurred over the stockpile and trench areas.

The reasons for these variations were not apparent, although they could be the result of a non-uniform distribution of species in the seeded grass/legume mixture.

e) Sites 85 and 86. These sites are on two, 4 year old gas pipelines in Solonetzic soils with a Barley crop cover. Topsoil was not salvaged along either line and 5 to 10 cm of shaly saline parent material (Csk) was left on the surface of both rights-of-way. Fifty-three to 82 percent reduction in cover was detected on all areas of each right-of-way except over the trench of site 85. Crop height and head varied from 11 percent less to 15 percent more than controls over the rights-of-way.

The decrease in cover appears to be the result of a layer of saline parent material left on the surface after reclamation. This effect may have been nullified over the trench at site 85 by the increased penetrability of the subsoil due to trenching.

f) Site 87. This site is located on a 4 year old 406.4 mm diameter gas pipeline in a Solonetzic soil area currently cropped to alfalfa. The topsoil was salvaged over the trench only, and when replaced it was mixed with the B horizon material over both the

trench and the stockpile area (10-15 cm depth). Over the working area, the saline parent material was mixed with the topsoil. The depth of topsoil in undisturbed areas was 13 to 16 cm.

Decreases in alfalfa cover and height occurred over the stockpile and working areas. Over the trench, there was little change in cover and a 55 percent increase in height. Dandelion cover increased on trench, stockpile and working areas.

Decreases in plant growth appear to be caused by the mixing of B horizon or saline parent material with topsoil over the stockpile and working areas. This effect appears to be reversed over the trench, possibly due to loosening of subsoil material and increased penetrability.

APPENDIX B

Characteristics of Sites With Vegetation Changes - Black Soil Zone

Decreases in percent live cover and/or plant height were observed on sites with the following characteristics:

a) Site 57. This site is located on a 2 year old 508 mm diameter gas pipeline installed during the winter. The area is characterized by fine textured Orthic Black Chernozems seeded to wheat. Topsoil was salvaged from the trench and stockpile areas. When replaced, the topsoil was mixed with C horizon material on the trench and mixed with B horizon material on the stockpile and working areas. Over the trench, finer texture, presence of carbonates, increased stone content and harder consistence was reflective of the topsoil-C horizon mixture. Live cover of wheat and crop height, decreased over the trench and stockpile areas while only a decreased live cover was noted over the working area.

The decrease in growth appears to be the result of extensive mixing and dilution of topsoil with B and/or C horizon material. The decrease was most severe over the trench where topsoil was mixed with the C horizon and least severe over the working area where the layer of topsoil-B horizon mixture was 10 cm deep and placed over original topsoil.

b) Site 59. This site is located on a 2 year old winter constructed, 508 mm diameter gas pipeline characterized by fine textured Orthic Black Chernozems seeded to wheat. Both topsoil and B horizon were salvaged. Over the trench, the replaced topsoil was mixed thoroughly with C horizon material to a depth of 22 cm. On the working area, layered topsoil, C horizon and topsoil-C horizon mixture was replaced to a depth of 50 cm. In the stockpile area, 12 cm of topsoil-B horizon mixture was replaced. Carbonates and a

fine texture present in the trench are indicative of the mixing outlined above.

The decreased wheat cover over the trench and working area appears to be the result of mixing and dilution of topsoil with C horizon material.

c) Site 19. This site is located on a 5 year old 406.4 mm diameter gas pipeline constructed during the summer. Soils are predominantly fine textured Orthic Black Chernozems seeded to wheat. Topsoil was salvaged from the trench only and replaced to a depth of 15 cm, however, it was mixed with C horizon material. Topsoil in working and stockpile areas were unmixed. There were noticeably less weeds (Canada thistle, Brome grass) on the working and stockpile area and no weeds on the trench.

Since no differences in stoniness, consistence or texture were observed, the reasons for decreased cover on working and stockpile areas is not readily apparent.

d) Site 68. This site is located on an 11 year old 254 mm diameter gas pipeline constructed during the summer. Imperfectly drained, Gleyed Black Chernozems under a cover of barley are the dominant soils. The topsoil was salvaged over the trench and replaced unmixed. There was no change in topsoil texture, stoniness or consistence throughout the right-of-way, although the soil appeared drier over the trench. Decreased crop cover and height was observed over the trench, while a decreased head length of 11 percent was noted over the working area.

Decreases in cover and height over the trench appears to be the result of increased drainage and/or a heated pipeline. The reason for decreased head length on the working area was not apparent.

e) Site 5a. This site is located on a 22 year old 914.4 mm diameter gas pipeline. Soils are fine textured Orthic Black Chernozems under a crop of barley. No topsoil was salvaged and as a result, a mixed upper horizon exists over the trench, stockpile and working areas. Over the trench, the texture appears to be finer and stinkweed is abundant.

The decrease in barley cover over the trench appears to be the result of the finer texture of the topsoil-C horizon mixture.

f) All native fescue pasture sites on Black Chernozemic soils. These pipelines vary from 1 to 22 years old, were constructed during both winter and summer, and vary from 3048 to 1067 mm diameter in size. The topsoil was generally mixed with C horizon over the entire right-of-way. Live vegetation cover and height differences are highly variable. Major vegetation effects are significant increases in weedy species and seeded grass/legume species different from controls. Sites where topsoil was unmixed had grass/legume species seeded. Pasture management problems arise as a result of species differences and weeds. Major weedy species observed are Canada thistle, stinkweed and mustard. One native fescue pasture site (WPb) was in its first growing season and the decreased height of vegetation is likely only temporary. This site was seeded with creeping red fescue. Salvaged topsoil was replaced only slightly mixed (some carbonates but no color, texture, or consistance differences) over the entire right-of-way. Many native

species were regenerating and an absence of weedy species such as Canada thistle and mustard was noted. Some timothy was present.

Effects observed appear to be the result of:

- topsoil-C horizon mixing;
- revegetation with grass/legume species uncompatible with native pasture management and use;
- cattle disturbance of right-of-way prior to vegetation reestablishment; and
- lack of follow up weed control while grass is reestablishing.

g) All improved forage crop sites on Black Chernozemic soils except sites 58, 65, 69a, 69b and 69c (exceptions are all Calcareous Black Chernozems except Site 65, which is an Orthic Black). The effects observed are generally the same as those noted in f). These appear to be the result of:

- topsoil mixing with C horizon;
- cattle disturbance of right-of-way prior to vegetation reestablishment;
- lack of follow up weed control while grass is reestablishing; and
- revegetation with species different from the remainder of the field. The compatibility of different species depends on site-specific management goals.

h) Site 60. This site is located on a 2 year old 508 mm diameter gas pipeline installed during the winter. The soils are fine textured Black Solodized Solonetz. No crop was seeded in the right-of-way

while adjacent areas were seeded to wheat. Topsoil was not salvaged and, as a result, some C horizon material was left on the trench surface. This is evident by the presence of crusting and salts on the trench surface. Crusting was also present in the stockpile and working areas although no salts were visible. There was a 3 percent cover of weeds in the trench, while a 60 percent cover of weeds was observed in the working and stockpile areas. The dominant weed is green smartweed.

These effects appear to be the result of:

- leaving saline soil parent material (C horizon) on the surface; and
- lack of follow up for leveling of mound over trench and weed control.

i) Site 61. This site is located on a two year old 508 mm diameter gas pipeline installed in winter. The soils are fine textured Black Solodized Solonetz under a crop of oats. The topsoil was not salvaged and the saline/sodic parent material was mixed with topsoil on the trench and stockpile areas. No such mixing occurred in the working area.

The decreases in oat crop live cover and height on trench and stockpile areas appear to be the result of mixing of saline/sodic parent material with topsoil.

j) Sites 55a and 55b. These sites are on gas pipelines in fine textured Black Solods planted to barley. Topsoil was salvaged on the trench. The replaced topsoil was unmixed except for over the

trench at Site 55b. Decreases in crop height and head length were observed over both trenches and in height only on the stockpile and working areas. The reasons for the decreases observed are not apparent although increased competition from weeds (wheatgrass, wild rose, wild oats) may be a cause.

k) Sites 62, 72a, 72b, 56a and 56b. These sites are improved forage crop sites on pipelines 2 to 19 years old, winter or summer constructed, on fine textured Black Solodized Solonetz or Solods. The topsoil was thoroughly mixed with the C horizon parent material over the surface of trenches and stockpile areas. The topsoil was unmixed on the working areas except for site 72b. Decreases in cover and height of crop were apparent where topsoil had been mixed with C horizon except when total cover or vegetation height increases where there was an increase in weedy species observed (particularly foxtail barley and plantain).

Effects appear to be the result of:

- topsoil-C horizon mixing; and
- increase in weedy species (foxtail barley and plantain).

Increases or little change in percent live cover and/or crop height were found on sites with the following conditions:

a) Entire right-of-way at 17 of the 23 annually cultivated Black Chernozemic sites. Topsoil was salvaged at most of these sites but the soil at the surface was mixed with the C horizon materials over trench, stockpile areas, and less frequently over the working area. Only two of the sites had unmixed topsoil over the entire right-of-

way. Barley was the predominant crop at most sites. Canola was grown at 2 of the 17 sites and an oats/barley mixture at another 3 sites. Where the topsoil was mixed, little or no change in soil stoniness or consistence was observed. These sites ranged in age from 1 to 19 years and from 203.2 mm to 609.6 mm diameter in size.

b) Site 19. This site occurs on a 5 year old, 406.4 mm diameter gas pipeline that has been seeded to wheat. Topsoil was not salvaged from the trench and was mixed when replaced. Topsoil was unmixed over both the stockpile and working areas. The wheat crop cover and height over the trench was less than 10 percent different than the adjacent control sites.

c) Sites 5a and 54b. These sites are situated on fine textured Orthic Black Chernozems planted with barley and canola respectively. The topsoil was not salvaged and as a result the soils are mixed throughout the entire rights-of-way excluding the working area of Site 54b. Decreases in crop cover and height were observed over the trench while little difference was noticed over the working and stockpile areas.

d) Sites 58, 69a, 69b and 69c. These four sites are located on pipelines varying in diameter from 203 mm to 609.6 mm. The soils are Calcareous Black Chernozems under improved forage crops. Topsoil was salvaged over the trench but replaced topsoil was mixed over the entire right-of-way. Crop characteristics were very uniform on both the right-of-way and the adjoining control areas.

e) Site 65. This site occurs on an 11 year old 254.0 mm diameter, summer constructed pipeline, placed in coarse textured Orthic Black

Chernozems. The area was cropped to timothy. The coarse textured topsoil was salvaged over the trench and stockpile areas. The replaced soil was slightly mixed in the stockpile area, but exhibited no change in stoniness or consistence.

f) Sites 71a and 71b. These two sites are situated on summer installed pipelines ranging in age from 5 to 19 years. The soils are dominantly fine textured Black Solodized Solonetz under a crop of barley. Topsoil was not salvaged at 71a and only salvaged over the trench at 71b. The only area where topsoil was not mixed or absent altogether was over the working area at 71a. Crop cover was 37 to 358 percent greater than controls and in general more uniform. No change in stoniness or consistence were noted except over trench of 71a where no topsoil replaced.

g) Sites 64a and 64b. These sites are located on pipelines installed during summer months, 19 and 5 years ago respectively. Soils were fine textured Black Solodized Solonetz under a crop of oats. Topsoil was salvaged over both trenches and was mixed upon replacement on all areas except the working and stockpile side of 64a. Only differences in crop height (decrease of 10 percent) were observed in the trench and stockpile areas of Site 64b. The other areas and sites showed less than 10 percent difference from the controls.

h) Site 3. This site is situated on an 11 year old, summer installed, gas pipeline 266.7 mm in diameter. Fine textured Black Solodized Solonetz are cropped to barley. Topsoil was salvaged over the trench but mixed upon replacement throughout the right-of-way. Less than 10 percent difference in crop cover and height was

observed over trench areas. A 10 percent decrease in plant height occurred over the trench and stockpile areas.

i) Site 67. This site is located on an 11 year old, 254 mm diameter pipeline that was installed in the summer. The soils are fine textured Black Solodized Solonetz seeded to an alfalfa/brome forage crop. Topsoil was salvaged over the trench and replaced on the trench unmixed. The C horizon materials were mixed with topsoil on the stockpile and working areas. Less than 10 percent difference exists in crop cover and height over the entire right-of-way as compared to the controls.

APPENDIX C

Characteristics of Sites With Decreased Vegetation - Dark Brown Soil Zone

Decreases in crop cover and height occurred on sites with the following characteristics:

a) Site 45. This site contains fine textured Orthic Dark Brown Chernozems on a 3 year old, summer constructed, 76.2 mm diameter gas pipeline. Topsoil was salvaged over the trench. A mixed topsoil-C horizon was replaced 10 to 20 cm deep over the right-of-way. Settling and surface cracks were evident over a loosely packed trench. The B horizon of the working area was harder than the controls. Fifty-one and 44 percent less wheat cover was evident over the trench and working areas respectively. Twenty percent less crop height occurred over the trench area. Less than a 10 percent difference from control areas was observed in the cover and height of vegetation over the stockpile area; crop head length over the entire right-of-way; and crop height over the working area.

Effects appear to be the result of:

- loosely packed trench; and
- compacted subsoil in working area.

b) Site 15. This site is situated on fine textured Orthic Dark Brown Chernozems over a 5 year old, summer constructed, 101.6 mm diameter gas pipeline. Topsoil was salvaged over the trench. A mixed topsoil-C horizon layer was replaced to a depth of 30 cm on the trench. Topsoil was unmixed over the stockpile and working areas, 10 to 15 cm deep. Control topsoil was generally 15 cm deep. Topsoil was looser and drier over the right-of-way. The loam texture remained unchanged. Wheat cover was 47 to 64 percent less

over the entire right-of-way, while wheat height was 11 to 31 percent less. Increased cover of wild rose was observed particularly in the stockpile area.

Reasons for reduced cover and height are not readily apparent, although the looser, drier topsoil may be one factor.

c) Site 17. This site occurs on fine textured Orthic Dark Brown Chernozems over a 5 year old, summer constructed, 406.4 mm diameter gas pipeline. Topsoil was not selectively salvaged according to the landowner. The topsoil on the trench and stockpile areas was slightly mixed. Topsoil was 10 cm deep over the trench and 20 cm deep over the stockpile and working areas. Topsoil was looser over the trench, stockpile and working areas. Barley cover was reduced 40 percent over the trench. Cover showed less than a 10 percent difference over the stockpile area while increasing by 32 percent over the working area. Crop height changed less than 10 percent, relative to controls over the entire right-of-way. Reduction in crop cover over the trench appears to be caused by the shallow depth and looseness of topsoil.

d) Sites 21 and 42. These sites are characterized by coarse textured Orthic Dark Brown Chernozems on 5 year old 406.4 and 203.2 mm diameter gas pipelines. Topsoil was salvaged only over the trench of the smaller pipeline. Over both pipelines, soil on the trench and stockpile areas was mixed topsoil and calcareous C horizon material. Mixed topsoil ranged from 10 to 15 cm deep. Working areas had unmixed topsoil.

The barley crop had reduced head length over the trench and stockpile areas (site 21). The wheat crop at site 42 had reduced cover over the trench and stockpile areas and reduced crop height over the trench. Canada thistle was common on the trench of site 21, while buckbrush was apparent on the working area only of site 42.

Reasons for crop effects are not readily apparent, although the possible immobilization of macronutrients in the coarse textured soils by the lime mixed into the topsoil may be a partial cause. This could be compounded by competition from weeds, particularly over the trench areas.

e) Site 39. This site is located in fine textured calcareous Dark Brown Chernozems over a 4 year old 203.2 mm diameter gas pipeline. The site is under sprinkle irrigation with a Durum wheat crop. Topsoil was not salvaged. Areas of trench settlement were rebackfilled by the landowner. Mixed topsoil-C horizon material was found 20 to 30 cm deep over the whole right-of-way. Subsoil (10 to 20 cm below surface) was firmer than control subsoil. Topsoil was observed to be drier over the right-of-way than the control.

Crop cover was 77 percent lower over the trench, stockpile and working areas than adjacent control. Crop height was also 13 percent lower over the trench area. Effects on the Durum wheat crop appear to be the result of:

- compacted subsoil layer and drier soils over right-of-way; and
- possibly compounded by additional lime in the mixed topsoil-C horizon material which may immobilize nutrients.

f) All native or improved forage crop sites on Dark Brown Chernozemic soils with pipelines from 5 to 6 years old, ranging in size from 76.2 to 406.4 mm can be evaluated as follows.

No topsoil was salvaged. Surface material over trench and stockpile areas was either calcareous C horizon only, or in a mixture with topsoil.

Effects include, reduced vegetation cover and height, and an increase in weedy species, including Canada thistle, foxtail barley, wild rose and buckbrush. These effects appear to be the result of:

- absence of topsoil or thorough mixing with calcareous C horizon material;
- compaction over trench and working areas (site 46); and
- gopher activity over trench.

APPENDIX D

Characteristics of Sites With Vegetation Changes - Brown Soil Zone

Decreases in vegetation cover and/or height were found at sites with the following characteristics:

a) Sites 32a, 32b, 32c and 32d. These sites are characterized by annually cultivated, coarse textured Orthic Brown Chernozems over 7 to 23 year old gas pipelines. Topsoil was not salvaged and mixed topsoil-C horizon material occurred 5 to 25 cm deep over the right-of-way. This material was finer textured, high in carbonates and firmer in consistence than adjacent undisturbed topsoil. The fall rye crop had a 38 to 48 percent decrease in cover and a general decrease in height and head length over the rights-of-way.

The effects on vegetation appear to be the result of topsoil mixing and possibly nutrient tie up from the presence of lime.

b) Sites 22a, 22b and 22c. These sites are located on annually cultivated, flood irrigated, fine textured Orthic Brown Chernozems over 12 to 23 year old gas pipelines. Topsoil was salvaged over the trench under wet soil conditions. The landowner indicated trench settlement had been a problem by concentrating and diverting water. Settlement was not evident at these sites during the study. Topsoil was mixed with calcareous C horizon material over the trench, stockpile and working areas. Subsoil was firm to very firm over the entire right-of-way. Barley crop cover and head length on rights-of-way were uniformly similar (less than 10 percent difference) to adjacent controls, however, crop height generally decreased over the rights-of-way by up to 19 percent. The landowner indicates that this effect is greater in drier years than 1981. These effects appear to be the result of:

- topsoil mixing; and
- subsoil compaction.

c) All dryland improved and native pasture sites can be summarized as follows. The pipelines ranged in age from 12 to 23 years old and no topsoil salvage was undertaken. Topsoil was mixed or absent over the trenches. Topsoil was either mixed or buried by a layer of calcareous C horizon material over most stockpile areas except those lacking topsoil originally (sand dune sites). Topsoil was unmixed over some of the working areas. Where finer textured subsoil was present alone or mixed with coarse textured topsoil on the surface, the soil was firmer or harder.

Vegetation cover and/or height changes were variable and generally attributable to the increased presence of a variety of weedy species. While these species, in some cases, result in comparable cover and increased vegetation height compared to control areas, their forage value is minimal.

These effects appear to be the result of:

- no topsoil salvage;
- calcareous parent material at the surface;
- mixing of topsoil and parent material over the stockpile and working areas; and
- lack of weed control following pipeline construction.

d) Sites 38a, 38b, 38c and 38d were annually cropped on fine textured Brown Solodized Solonetz over 7 to 23 year old gas pipelines. Topsoil was salvaged over the trenches at these sites and mixed

with C horizon material at all locations on the rights-of-way except the working area of site 38d (7 years old). Finer textured material was found over the older trenches (38a and 38b). Trench subsoil was looser than the control soils and stockpile and working area subsoils except the trench of 38c where the parent material at 15 cm was firm.

The wheat crop at these sites had from 13 to 37 percent decrease in height on the stockpile and working areas and over the trench at 38c. Head length decreased by 11 percent or less at all locations.

Effects appear to be the result of:

- mixed topsoil and subsoil over very firm or hard subsoils (Bnt) on stockpile and working areas.

e) All native forage sites on Brown Solonetzic soils are over gas pipelines from 7 to 23 years old. No topsoil was salvaged. C horizon material was found at the surface of all trenches and stockpile sites and on the working areas of 12 of the 15 sites. The depth of C horizon material varied from 2 to 45 cm over the stockpile and working areas.

Vegetation cover decreased at most sites while height increased. Weedy species were more abundant over the entire right-of-way at all sites than on adjacent control areas. Weedy species included foxtail barley, sage, gumweed and broomweed. The increase in weedy species and overall reduction in cover on sites of all ages from 7 to 23 years old appears to be the result of calcareous saline parent material covering the surface of most rights-of-way. Little

change or increases in crop cover and height were evident at sites with the following characteristics:

i) Sites 24a, 24b and 24c. Calcareous Brown Chernozem with 12, 17 and 23 year old gas pipelines. Topsoil was salvaged and replaced over trenches. Topsoil texture was firmer on stockpile areas and exhibits firmer or harder consistence over the stockpile areas and the oldest trench. Less than 10 percent difference in clover/bluegrass cover occurred. The pasture is irrigated and grazed. The landowner indicates that crop cover has been reduced over the trenches in previous years either as a result of the heated lines and drier soil or because of the finer texture and harder consistence.

ii) Sites 26a, 26b and 26c. These sites are fine textured, Brown Solodized Solonetzic soils with 12, 17 and 23 year old gas pipelines. Topsoil was mixed with some C horizon material over trench and stockpile areas. Topsoil over the other working areas was unchanged from adjacent control areas. Barley crop cover and height was generally greater over rights-of-way than controls. Head lengths have less than 10 percent deviation from controls.

iii) Sites 31a and 31b. These sites are situated on fine textured Brown Solodized Solonetz. Topsoil was salvaged over the entire right-of-way and replaced unmixed. The wheat crop cover height and head length was less than 10 percent different than adjacent control areas.

APPENDIX E

Landowner/Farmer Questionnaire

QUESTIONNAIRE

1) When was the pipeline constructed (summer/winter, month)?

2) Was the pipeline right-of-way clearly defined and staked?

3) Was topsoil stripped prior to excavation of the ditch?

4) To what depth (approximately) was topsoil stripped?

5) What were the soil moisture conditions at the time of construction (dry, moist, wet)?

6) Was the topsoil placed on the same side of the ditch as the subsoil or the opposite side?

7) During the actual construction of the pipeline, how severe (negligible, minor, major) were interruptions to farming practices such as:

   a) Inability to cross pipeline ditch with machinery?

   b) Necessity to keep livestock away from the construction area?

8) Immediately following pipeline construction and cleanup, was additional work required along the trench and/or right-of-way in order to improve the ground surface (e.g., cultivating, contouring, stone picking)?

If additional work was needed, who conducted it? The pipeline construction company, yourself, or others?

9) Was the pipeline trench and/or right-of-way reseeded after construction?

   a) How long after construction did reseeding take place?

   b) Type of seed (seed mix) and amount used?

   c) Was fertilizer added as well (type and amount)?

   d) Who conducted seeding and fertilizing?

10) Has seed establishment been affected along the trench and/or right-of-way as compared to the adjacent field?

11) Has crop yield been affected along the trench and/or right-of-way?

   a) Has the yield increased or decreased?

   b) How long after construction has crop yield been affected?

   c) Is the effect on crop yield the same for all crops?

12) Have different procedures been used along the trench and/or right-of-way, as compared to the adjacent field areas, in order to increase productivity (e.g., special or additional application of herbicides and/or fertilizer, additional seedbed preparation)?

13) Are problems encountered along the pipeline trench and/or right-of-way that affect machine operation (e.g., access, number of stones, poor trafficability, eroded areas, etc.) resulting in difficulties associated with crop harvesting?

14) Has pipeline construction resulted in alterations to drainage patterns in the area, leading to excessively wet or dry areas?

15) Were any other problems encountered as a result of the pipeline construction crew's methods (e.g., garbage left on land, fuel spills, failure to keep construction equipment within the right-of-way boundaries)?

Additional Comments

APPENDIX F

Site Legal Locations

F1. Site Locations - Gray Soil Zone/Peace River region.

F2. Site Locations - Dark Brown Soil Zone.

Site Number	Legal Location	Site Number	Legal Location
76A	SE 28-51-3 W5	45	NW 3-15-23 W4
76B	SE 28-51-3 W5	13	SW 6-20-25 W4
77A	NE 29-51-3 W5	15	SE 7-20-25 W4
77B	NE 29-51-3 W5	17	NE 22-23-26 W4
63	SE 32-54-10 W4	21	SW 4-26-25 W4
84	NE 31-78-8 W6	42	SE 17-8-20 W4
74C	SW 4-55-2 W5	39	NE 10-8-21 W4
82	SW 15-81-2 W6	11	SE 4-20-27 W4
74D	SW 4-55-2 W5	43	NE 25-10-26 W4
74A	SW 4-55-2 W5	47	NE 11-14-23 W4
74B	SW 4-55-2 W5	46	NW 12-15-23 W4
88	NE 24-76-4 W6	40	NE 11-8-21 W4
75C	SW 4-55-2 W5	14	NE 7-20-25 W4
78B	SE 11-55-3 W5	41	SW 16-8-20 W4
75D	SW 4-55-2 W5	16	SE 22-23-26 W4
78A	SE 11-55-3 W5	12	SW 4-20-26 W4
75A	SW 4-55-2 W5	10	SW 4-20-27 W4
75B	SW 4-55-2 W5	44	NE 24-10-26 W4
78C	SE 11-55-3 W5	28D	NE 18-20-10 W4
78D	SE 11-55-3 W5	28C	NE 18-20-10 W4
85	SW 11-78-1 W6	28B	NE 18-20-10 W4
86	SW 16-78-1 W6	28D	NE 18-20-10 W4
87	SE 18-18-1 W6		
83	SE 15-81-2 W6		

F3. Site Locations - Black Soil Zone.

Site Number	Legal Location	Site Number	Legal Location
49	NE 14-43-25 W4	71A	SW 8-54-26 W4
52	NE 13-43-25 W4	55B	SE 26-44-16 W4
50	NE 13-43-25 W4	WPB	NW 31-11-1 W5
80	NE 31-42-22 W4	53	NW 7-43-23 W4
81	SW 20-40-22 W4	51	SE 16-43-24 W4
57	SE 35-51-16 W4	79	NW 19-42-22 W4
59	NW 34-52-17 W4	9B	SE 17-21-29 W4
8	SW 17-25-5 W5	58	NW 25-51-16 W4
5B	SE 6-18-2 W5	6A	NE 9-16-2 W5
70A	NE 31-50-25 W4	48A	SE 27-14-2 W5
73B	SE 33-54-23 W4	4	SE 16-25-5 W5
18	SW 26-23-26 W4	7	SW 16-25-5 W5
19	SE 2-24-26 W4	69A	SW 31-50-28 W4
54A	SW 2-44-16 W4	20	NW 8-25-25 W4
68	SE 24-46-26 W4	65	SE 29-48-25 W4
66	SE 29-48-25 W4	1	SE 18-25-28 W4
2	SE 18-25-28 W4	6C	NE 9-16-2 W5
5C	SE 6-18-2 W5	48B	SE 27-14-2 W5
73A	SE 33-54-23 W4	48C	SE 27-14-2 W5
5A	SE 6-18-2 W5	6B	NE 9-16-2 W5
54B	SW 2-44-16 W4	WPA	NW 31-11-1 W5
70B	NE 31-50-25 W4	9A	SE 17-21-29 W4
70C	NE 31-50-25 W4	69B	SW 31-50-28 W4
60	NE 28-53-18 W4	69C	SW 31-50-28 W4
61	SE 33-53-18 W4	62	SE 33-53-18 W4
64B	NE 26-54-24 W4	72B	SE 8-54-26 W4
71B	SW 8-54-26 W4	56A	NE 23-44-16 W4
55A	SE 26-44-16 W4	67	SE 6-48-25 W4
3	NW 20-27-28 W4	72A	SE 8-54-26 W4
64A	NE 26-54-24 W4	56B	NE 23-44-16 W4

F4. Site Locations - Brown Soil Zone.

Site Number	Legal Location	Site Number	Legal Location
32D	SW 15-20-2 W4	38D	NW 16-20-10 W4
22C	NW 4-23-16 W4	38C	NW 16-20-10 W4
32C	SW 15-20-2 W4	26C	SE 16-21-13 W4
32B	SW 15-20-2 W4	26B	SE 16-21-13 W4
22B	NW 4-23-16 W4	38B	NW 16-20-10 W4
22A	NW 4-23-16 W4	31A	NE 22-23-12 W4
32A	SW 15-20-2 W4	38A	NW 16-20-10 W4
34D	NE 10-20-2 W4	26A	SE 16-21-13 W4
33D	SE 16-20-2 W4	31B	NE 22-23-12 W4
24C	NE 28-20-12 W4	35A	NW 11-18-10 W4
33C	SE 16-20-2 W4	36A	NW 23-18-20 W4
25C	SE 16-20-12 W4	37D	NE 17-20-10 W4
34C	NE 10-20-2 W4	37C	NE 17-20-10 W4
23C	SE 7-22-14 W4	27C	SW 15-21-13 W4
23B	SE 7-22-14 W4	27B	SW 15-21-13 W4
34B	NE 10-20-2 W4	37B	NE 17-20-10 W4
25B	SE 16-20-12 W4	29A	SE 9-24-12 W4
33B	SE 16-20-2 W4	30A	NW 33-24-12 W4
24B	NE 28-20-12 W4	27A	SW 15-21-13 W4
24A	NE 28-20-12 W4	37A	NE 17-20-10 W4
33A	SE 16-20-2 W4	35B	NW 11-18-10 W4
25A	SE 16-20-12 W4	30B	NW 33-24-12 W4
34A	NE 10-20-2 W4	36B	NW 23-18-10 W4
23A	SE 7-22-14 W4	29B	SE 9-24-12 W4

APPENDIX G

Analysis of Topsoil Samples at Selected Sites

G1. Analysis of topsoil samples at selected sites.

Site No.	Topsoil Sample Location	pH	Conductivity mmhos/cm	Available Nutrients (ppm) NO_3-N	P	K	SO_4-S	Exchangeable Cations (ppm) Na+	Ca++	% $CaCO_3$ Equivalent	% O.M.
55a	Control	5.9	0.2	4	5	325	6	20	2640	0.53	8.50
55a	Stockpile	6.6	0.3	5	5	195	9	40	2550	1.06	6.14
55a	Trench	7.3	0.6	5	4	135	60	120	3080	1.06	3.67
55b	Trench	7.3	0.8	5	7	125	110	35	3580	1.06	3.38
55b	Work Area	7.4	0.4	4	7	180	30	70	2650	0.53	5.18
55b	Stockpile	7.5	0.4	3	5	130	60	40	3110	1.06	2.88
61	Control	6.1	0.2	5	5	50	25	625	1930	-	7.38
61	Stockpile	5.4	0.8	62	9	65	70	795	1130	-	6.79
61	Trench	6.0	1.4	70	8	90	200	1310	1860	-	6.14
61	Work Area	5.7	0.3	11	8	65	40	715	1120	-	6.55
71b	Control	6.0	0.4	8	11	115	40	990	2220	-	8.62
71b	Stockpile	6.7	0.4	7	12	145	25	240	3790	-	7.26
71b	Trench	7.5	0.4	6	12	190	35	210	5100	-	4.43
71a	Stockpile	7.6	0.3	7	12	175	25	155	5090	-	5.02
71a	Trench	7.5	0.3	5	14	145	20	235	4580	-	5.93
71a	Work Area	7.3	0.3	4	9	120	25	565	3620	-	5.26
74a	Control	6.7	0.2	4	8	70	3	-	-	-	3.41
74a	Work Area	6.7	0.2	2	7	85	2	-	-	-	2.21
74a	Trench	6.9	0.2	3	6	90	3	-	-	-	1.82
74a	Stockpile	6.7	0.2	2	7	80	2	-	-	-	2.33
77b	Control	6.0	0.2	6	8	110	4	-	-	0.53	7.38
77b	Trench	7.5	0.4	3	6	135	20	-	-	1.06	2.69
77b	Work Area	7.7	0.3	2	7	145	20	-	-	1.58	2.83

G2. Detailed salinity analysis data.

Site No.	Topsoil Sample Location	Percent Saturation	pH	Conductivity mmhos/cm	Water Soluble Ions (ppm)						
					Na	Ca	Mg	K	Cl	SO_4	SAR
61	Control	57	5.7	0.8	207	11	9	11	25	255	11.2
61	Stockpile	53	5.4	1.0	650	38	38	5	6	650	17.8
61	Trench	53	5.9	5.8	1090	106	77	9	9	2900	19.7
61	Work Area	49	5.5	0.7	223	7	6	12	18	400	14.9
71b	Control	65	5.8	1.0	240	10	28	2	13	420	8.8
71b	Stockpile	65	6.9	1.0	107	31	30	6	11	200	3.3
71b	Trench	72	7.4	0.8	107	31	30	6	11	200	3.3
71a	Stockpile	65	7.5	1.3	57	25	19	5	6	210	2.1
71a	Trench	68	7.5	1.0	76	19	13	4	18	90	3.3
71a	Work Area	60	6.9	0.8	68	31	18	6	5	205	2.4